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Space Industrialization

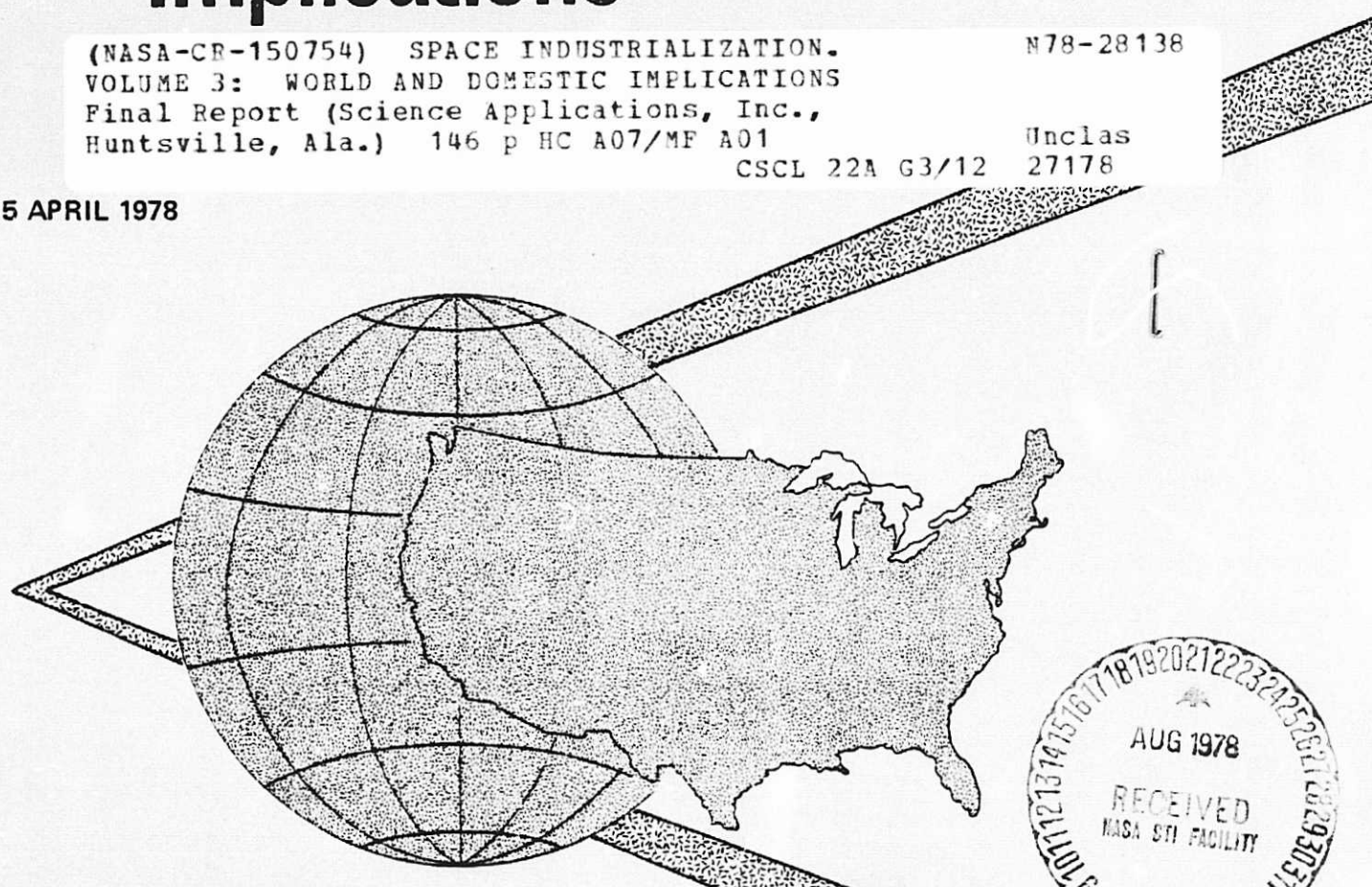
World and Domestic Implications

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FINAL REPORT

VOLUME 3

SPACE INDUSTRIALIZATION
SCIENCE APPLICATIONS, INC

SAI-79-604-HU

SPACE INDUSTRIALIZATION STUDY

FINAL REPORT - VOL 3

SPACE INDUSTRIALIZATION
- WORLD AND DOMESTIC IMPLICATIONS

PREPARED UNDER NASA CONTRACT NAS8-32197

APRIL 15, 1978

S C I E N C E A P P L I C A T I O N S, I N C.
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FOREWORD

This $198,962.00 Space Industrialization Study was performed under NASA Contract NAS8-32197 for Marshall Space Flight Center from September 1976 through April 1978. The study was in two parts: Part 1 identified the future opportunities for space industrialization, quantified the potential benefits and developed and analyzed evolutionary program options required to take advantage of these opportunities; Part 2 defined the framework of international governmental, industrial, legal and economic constraints within which space industrialization (SI) must evolve. Step-by-step guidelines to implementation of programs to capitalize on the SI opportunities were formulated using information from Part 1 and Part 2. The study results are documented in four volumes:

1. SPACE INDUSTRIALIZATION - AN OVERVIEW
2. SPACE INDUSTRIALIZATION - OPPORTUNITIES, MARKETS AND PROGRAMS
3. SPACE INDUSTRIALIZATION - WORLD AND DOMESTIC IMPLICATIONS
4. APPENDICES

Part 1 of the study was managed by Dr. Ralph Sklarew and Part 2 by Mr. Gerald W. Driggers. Other key SAI participants were Mr. E. Battison, Mr. D. Davis, Mr. Sam Gibson, Mr. Mark Klan and Mr. Gordon Collyer. A large portion of the work reported here was accomplished by consultants who occupied roles as principal investigators. The key consultants were:

- Mr. Robert Salkeld - System Planning and Programmatics
- Mr. G. Harry Stine - Industrial Planning and Marketing
- Mr. Paul Siegler - Market Assessment and Economic Analysis
- Dr. J. Peter Vajk - World Dynamics and Futures Assessment

A subcontract to Southern Research Institute (SoRI) in Birmingham, Alabama, was managed by Mr. Driggers during Part 1 of the study, prior to his joining SAI. Key participants at SoRI were Mr. S. J. Causey and Mr. R. Monroe.

Certain individuals within, and with no affiliation to SAI, provided valuable informal data, comments and guidance during the study. The following are recognized for their special contributions.

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- Dr. Peter Glaser

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The study was performed under the technical direction of Mr. Rodney Bradford (Part 1) and Mr. Georg von Tiesenhausen (Part 2), Marshall Space Flight Center. Mr. J. von Puttkamer was the program manager for NASA Headquarters, Office of Space Transportation Systems.

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TABLE OF CONTENTS

Section		Page
1	INTRODUCTION	1
2	WORLDWIDE ACTIVITIES IN SPACE INDUSTRIALIZATION AND THEIR IMPLICATIONS	3
	2.1 WORLDWIDE ACTIVITIES IN SPACE INDUSTRIALIZATION	6
	2.2 POTENTIAL WORLD IMPLICATIONS	25
	2.2.1 Indonesia	29
	2.2.2 Niger	34
	2.2.3 India	39
	2.2.4 Brazil	46
	2.2.5 Environmental Issues of Space Industrialization	51
3	DOMESTIC IMPACT AND ISSUES	59
	3.1 EMPLOYMENT AND ECONOMY IMPACTS	59
	3.1.1 Assumptions	61
	3.1.2 Results	62
	3.2 SAMPLE INDUSTRY COMMENTS AND RECOMMENDATIONS	64
	3.2.1 Perceptions	64
	3.2.2 Industry Views on Roles and Responsibilities	66
	3.2.3 Specific Feedback and Recommendations	68
4	LEGAL CONSIDERATIONS	76
	4.1 INTERNATIONAL LAW	76
	4.2 DOMESTIC LAW AND POLICY	77
	4.3 SUMMARY	78
5	INSTITUTIONAL IMPLICATIONS	79
	5.1 OVERVIEW	79
	5.2 FIVE SIGNIFICANT CONSIDERATIONS	86
6	CAPITAL REQUIREMENTS AND ECONOMIC VIABILITY	89
	6.1 MARKET POTENTIAL DETERMINATION: ELECTRONIC MAIL (REVISION 1)	90

TABLE OF CONTENTS
(Continued)

Section		Page
	6.2 GROUNDRULES AND ASSUMPTIONS	90
	6.3 METHODOLOGY	95
	6.4 RESULTS OF ASSESSMENT STEPS	96
	6.4.1 Number of Channels Needed in a National Teleconferencing Net	96
	6.4.2 Number of Channels Needed in a National Personal Communications Net	97
	6.4.3 Number of Channels Used by Business in a National Information Service (Volume 2)	98
	6.4.4 Profit Margins as a Function of Total Revenue	99
	6.4.5 Rate of Return and Cash Flow Analysis	106
	6.4.6 General Conclusions	117
	6.5 ECONOMIC VIABILITY ASSESSMENT SUMMARY	118
7	OBSERVATIONS AND RECOMMENDATIONS	121
	7.1 OBSERVATIONS	121
	7.2 KEY TECHNOLOGIES	124
	7.3 RECOMMENDATIONS	127
	7.3.1 General Recommendations	127
	7.3.2 Specific Recommendations	128
	7.4 STUDY RECOMMENDATION DESCRIPTORS	131

LIST OF ILLUSTRATIONS

Figure		Page
2-1	Space Industrialization - 20 years later	4
2-2	Worldwide SI Capability Summary.	5
2-3	Indicative SI Growth Rates	7
2-4	Worldwide Space Capability Matrix (as of 3/78)	8
2-5	Some European-Middle East Organizations Aimed at Space Industrialization.	17
2-6	Number of Major Communication Satellites Launched vs. Time (Excluding U.S.S.R.)	18
2-7	Evolution of World SI Activities	26
3-1	Schematic Summary of Perceptions by Industry Contacts Regarding the Present Status and Probable Future of Levels of Risk in Space Industrialization	65
3-2	Industry Views on Roles and Responsibilities	67
5-1	Five Significant Considerations	88
6-1	500 KW Geosynchronous Platform	93
6-2	Antenna Locations for the Geosynchronous Platform	94
6-3	Cumulative Cash Flow Requirements	120
7-1	The How and Why of Space Industrialization	122
7-2	The Baseline Scenario Projection of What Space Industrialization Will Be Composed of and When Revenues Will Result	123
7-3	SI Structures, Power and Transport Requirements	126
7-4	Recommendations for Study and Planning Activities Leading to Implementation of SI Programs	129

LIST OF TABLES

Table		Page
2-1	Some European-Middle East Organizations Aimed at Space Industrialization	16
2-2	Some Current and Planned International Space Industrialization Activities (Excluding USSR, CPR)	22
6-1	Revised Revenue Potential for Electronic Mail at a Reduced Annual Volume of 12 Billion Pieces	91
6-2	Electronic Mail	101
6-3	Teleconferencing	102
6-4	Personal Communication (Portable Telephone)	103
6-5	National Information Service	104
6-6	Direct Television	105

1. INTRODUCTION

This is Volume 3 in a four volume series that is the Final Report on the Space Industrialization Study conducted by Science Applications, Incorporated (SAI) for the National Aeronautics and Space Administration (NASA) as discussed in the Preface.

The data presented in this volume were derived to provide initial ("first cut") answers to the following questions.

- What is the status of worldwide Space Industrialization (SI) activities?
- What benefits can be anticipated from enhanced SI activities?
- How can SI growth be stimulated?

Several areas of investigation were addressed and the results applied to answering the above questions. The areas investigated were:

- Foreign and International Activities
- National and World Impact Assessments
- Industry/Government Interfaces
- Legal Implications
- Institutional Implications
- Economics and Capitalization
- Implementation Issues and Recommendations

The sequence given here corresponds to the major sections in this volume where results from each investigation appear. However, data from several of these areas cross-feed to several portions of the report. In particular, Section 7 on Observations and Recommendations is a synthesis of all areas of investigation. By assigning these areas (above) of broad interest first it was possible to begin in a very general way and converge on answers to the three questions asked earlier as knowledge and insight were gained.

The data in this volume is of major significance in that it is a first step in addressing the most difficult of all issues: national and international implementation of bold new initiatives in space industrialization. Solving the technology development problems will be straightforward. Insuring the timely, beneficial implementation of programs to develop and use the prerequisite technology is the truly difficult issue. This study provides the framework and general guidance required to begin insuring such implementation.

2. WORLDWIDE ACTIVITIES IN SPACE INDUSTRIALIZATION AND THEIR IMPLICATIONS

From military and scientific beginnings some twenty years ago (October 1957 for Sputnik, January 1958 for Explorer) there has evolved a broad and complex industrial base in space. The activities range from basic research in the space processing of materials to the fully operational information transfer systems as illustrated on Figure 2-1. The worldwide gross annual revenue now exceeds one billion dollars in sales of services alone. Current published projections indicate that revenues from services by 2000 may reach ten to twenty billion dollars given only minor extrapolations of present technology. With technology advancements in power, structures, transportation, materials processing, frequency use and data handling our study indicates that the potential can be several times that revenue amount. Of the four general categories of space industrialization (Information Services, Products, Energy, People in Space) the area nearest maturity is Information Services. New technologies will be necessary to open up new markets in these services also, however.

The worldwide interest in SI is reflected by the number of countries and agencies that are actively participating at present. This is characterized in Figure 2-2 by summarizing capabilities both previously demonstrated and currently being developed that relate specifically to Space Industrialization. Although manned capabilities are dominated by the USA and USSR the fruits of SI techologies are being used broadly as demonstrated by the first two columns. Also significant is the extensive involvement of nations and international organizations in unmanned activities. This would indicate that the unique technologies most significant to US future exploitation in SI would be those associated with manned space flight, particularly shuttle related capabilities.

The bottom line (both figuratively and literally) of Figure 2-2 carries a significant message: space industrialization is a strong, viable international and multinational endeavor. This chart establishs the status of SI in the world by illustrating current capability and utilization, all of which has evolved in the last twenty years. A related question of some immediate interest is then whether this growth continues or has it reached

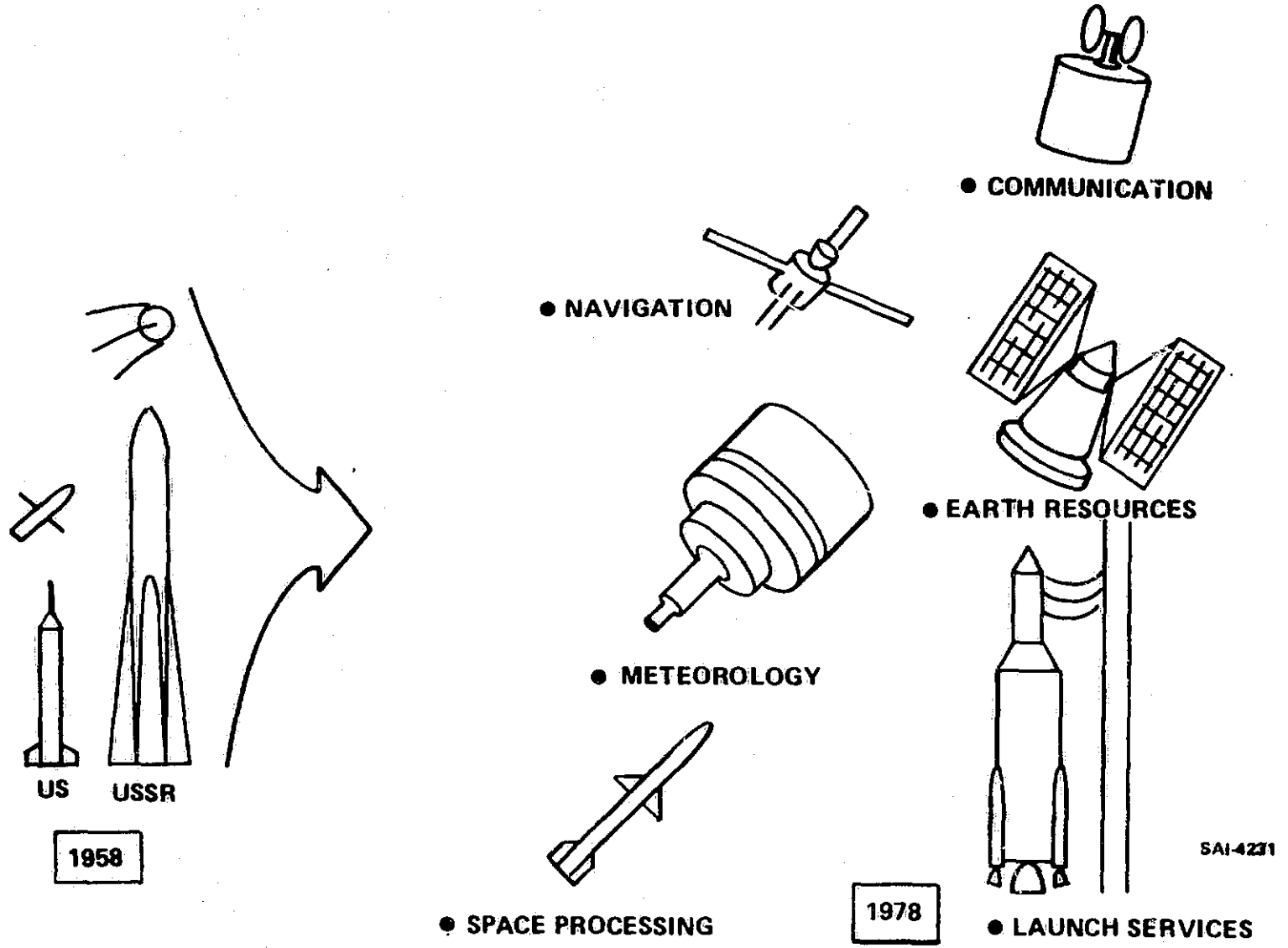
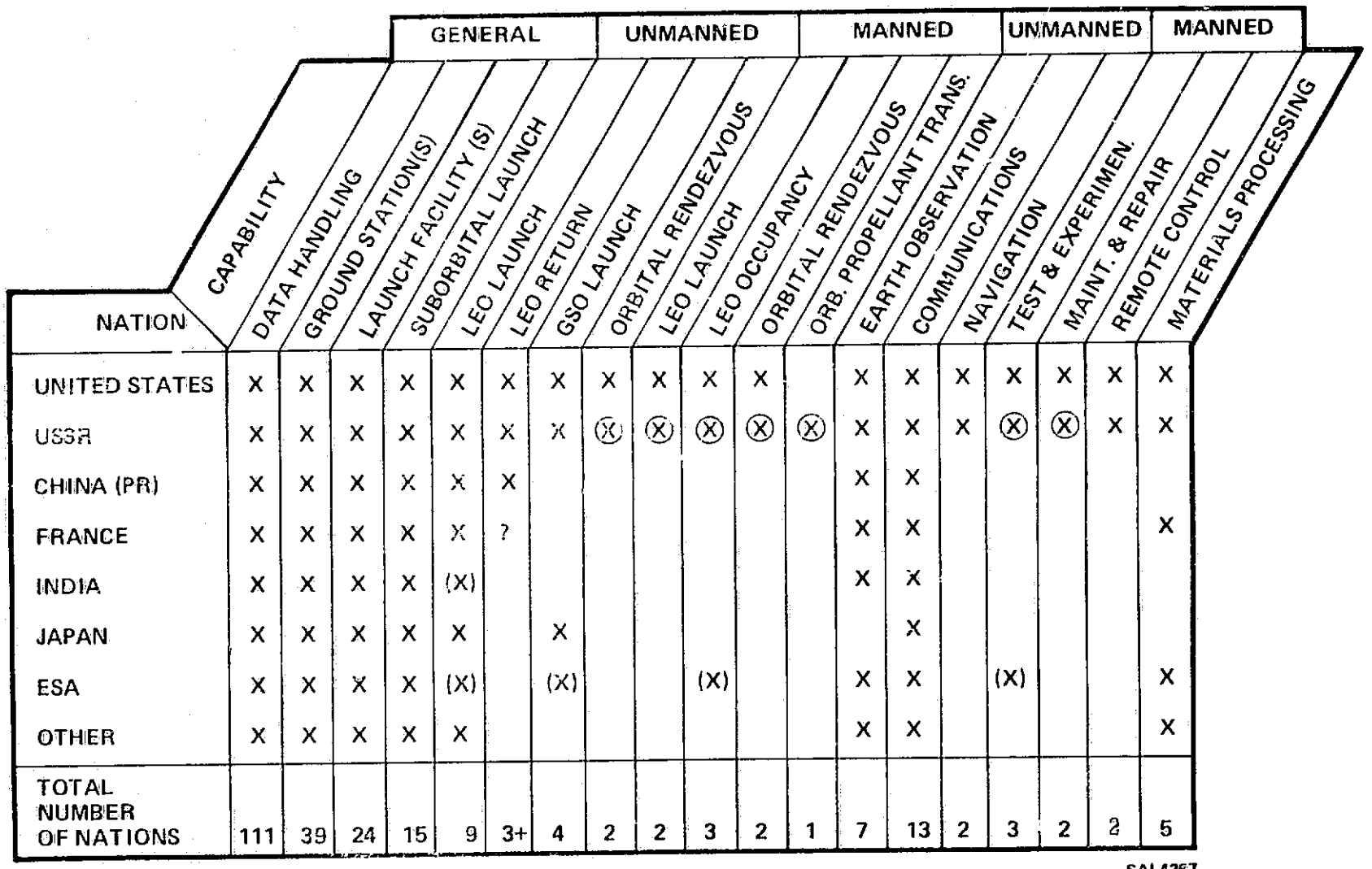


Figure 2-1. Space Industrialization - 20 Years Later



	GENERAL							UNMANNED				MANNED			UNMANNED		MANNED		
NATION / CAPABILITY	DATA HANDLING	GROUND STATION(S)	LAUNCH FACILITY (S)	SUBORBITAL LAUNCH	LEO LAUNCH	LEO RETURN	GSO LAUNCH	ORBITAL RENDEZVOUS	LEO LAUNCH	LEO OCCUPANCY	ORBITAL RENDEZVOUS	ORB. PROPELLANT TRANS.	EARTH OBSERVATION	COMMUNICATIONS	NAVIGATION	TEST & EXPERIMEN.	MAINT. & REPAIR	REMOTE CONTROL	MATERIALS PROCESSING
UNITED STATES	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
USSR	X	X	X	X	X	X	X	Ⓧ	Ⓧ	Ⓧ	Ⓧ	Ⓧ	X	X	X	Ⓧ	Ⓧ	X	X
CHINA (PR)	X	X	X	X	X	X							X	X					
FRANCE	X	X	X	X	X	?							X	X					X
INDIA	X	X	X	X	(X)								X	X					
JAPAN	X	X	X	X	X		X							X					
ESA	X	X	X	X	(X)		(X)			(X)			X	X		(X)			X
OTHER	X	X	X	X	X								X	X					X
TOTAL NUMBER OF NATIONS	111	39	24	15	9	3+	4	2	2	3	2	1	7	13	2	3	2	2	5

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(X) Indicates to be demonstrated by 1981. Ⓧ Indicates currently unique capability

X Indicates capability has been demonstrated.

Figure 2-2. Worldwide SI Capability Summary

a plateau. This question has been addressed by examining the growth rate and plans of several "mature" SI activities. Two of these growth trends are illustrated on Figure 2-3; one is transportation capability to LEO and the second is ownership of communication satellites by nations or organizations. Launch capability continues to show a linear trend while communication satellite ownership appears to be growing exponentially. Other service applications (remote sensing, navigation, etc.) show similar trends. As an indication of how recognition times may be shortening for new SI technologies it is interesting to observe that at least five nations are now sponsoring materials space processing research with at least three organizations or nations actively conducting launches.

The following sections of this report present the status of the worldwide activities in greater detail and explore their potential implications.

2.1 WORLDWIDE ACTIVITIES IN SPACE INDUSTRIALIZATION

The matrix of Figure 2-4 shows the degree of commitment to space industrialization on a worldwide basis which already exists. It lists key space capabilities in order of increasing sophistication, beginning with basic data handling, which all members of Intelsat and Intersputnik possess, up through space transportation and various space operational capacities both unmanned and manned. Against these capabilities it lists individual nations and groupings of nations (e.g., ESA) which are involved in space industrial activities.

It is immediately apparent that information handling is a space industry already well established on a commercial basis and in which are involved most of the nations of the world. One hundred eleven nations currently have capability to receive, transmit and process space information systems data. Thirty-nine nations operate their own ground stations for space information processing. Twenty-four nations operate their own launch facilities in support of suborbital or orbital rocket launch operations, and fifteen nations have independent suborbital rocket launch capability for space exploration and experimental purposes. Eight nations or multinational groups have capability to launch payloads to low-

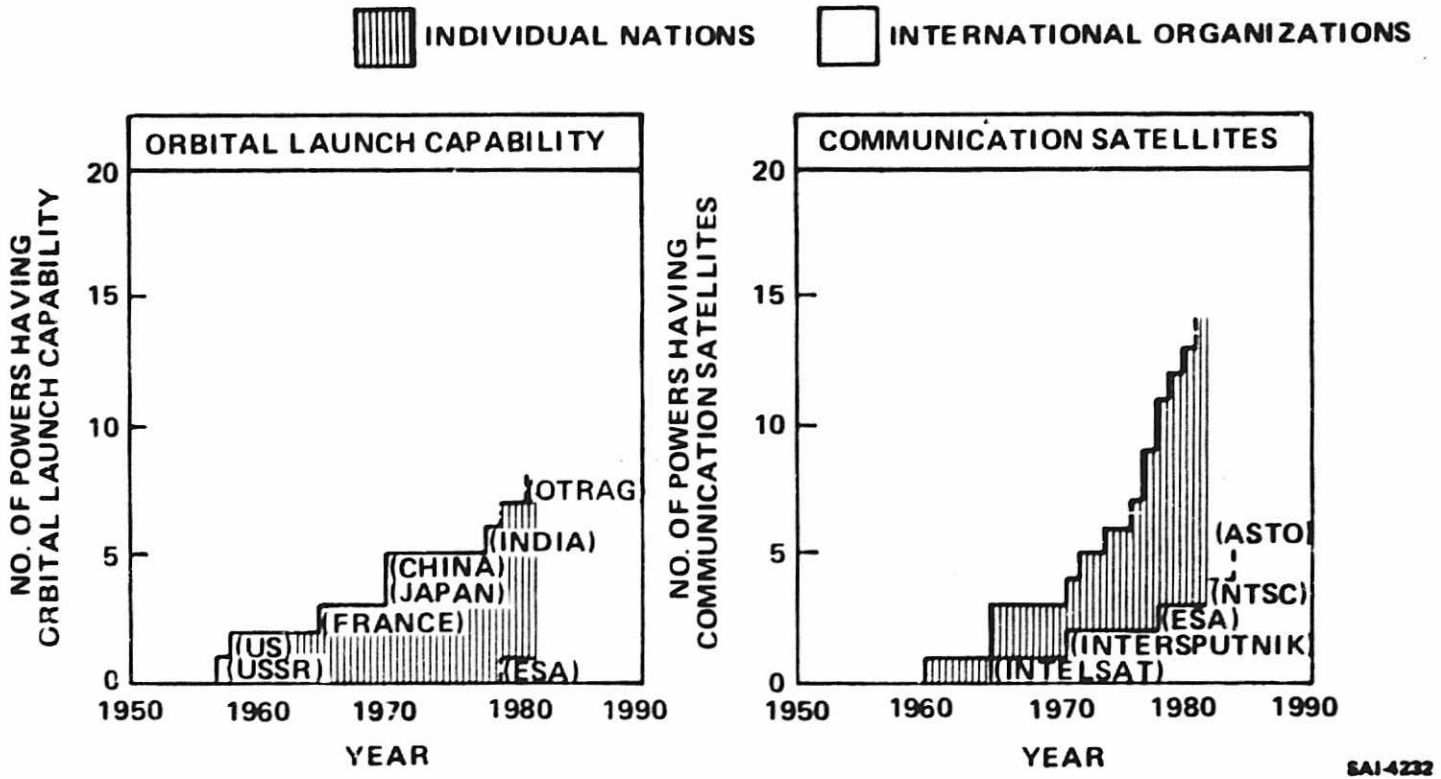


Figure 2-3. Indicative SI Growth Rates

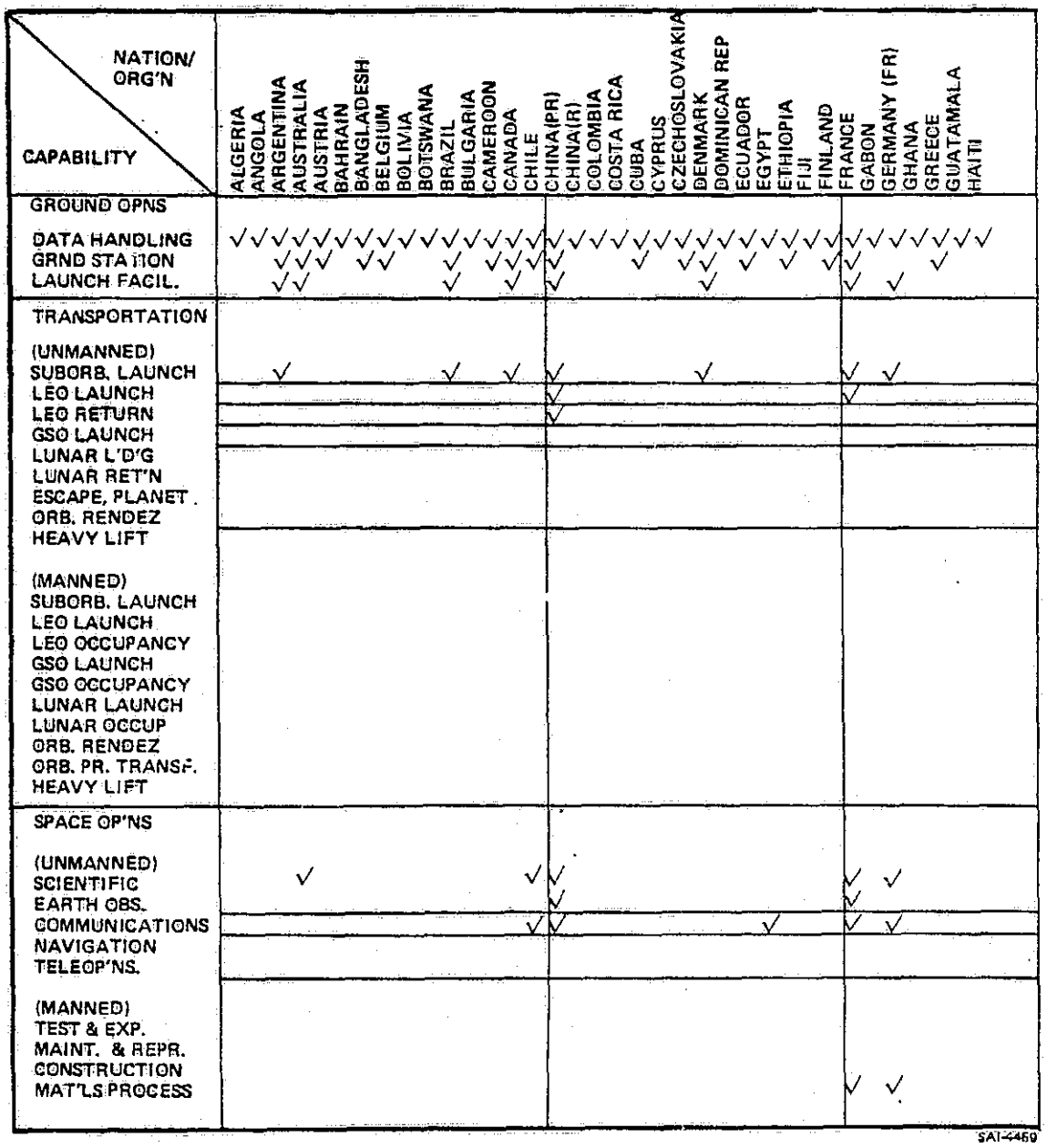


Figure 2-4. Worldwide Space Capability Matrix (as of 3/78)

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NATION/ ORG'N / CAPABILITY	HUNGARY	ICELAND	INDIA	INDONESIA	IRAN	IRAQ	IRELAND	ISRAEL	ITALY	IVORY COAST	JAMAICA	JAPAN	JORDAN	KENYA	KOREA (S)	KUWAIT	LEBANON	LESOTHO	LIBERIA	LIBYA	LICHTENSTEIN	LUXEMBOURG	MADAGASCAR	MAYLASIA	MALI	MALTA	MAURITANIA	MAURITIUS	MEXICO	MONACO	MONGOLIA	MOZAMBIQUE	NAURU	NETHERLANDS	NEW ZEALAND	NICARAGUA	NIGERIA
GROUND OPNS																																					
DATA HANDLING	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
GRND STATION			✓	✓	✓				✓			✓		✓										✓		✓			✓					✓			
LAUNCH FACIL.			✓						✓			✓																	✓					✓	✓		✓
TRANSPORTATION																																					
(UNMANNED)																																					
SUBORB. LAUNCH			✓									✓																									
LEO LAUNCH			✓	SLV–3								✓																									
LEO RETURN																																					
GSO LAUNCH												✓																									
LUNAR L'D'G																																					
LUNAR RET'N																																					
ESCAPE, PLANET																																					
ORB. RENDEZ																																					
HEAVY LIFT																																					
(MANNED)																																					
SUBORB. LAUNCH																																					
LEO LAUNCH																																					
LEO OCCUPANCY																																					
GSO LAUNCH																																					
GSO OCCUPANCY																																					
LUNAR LAUNCH																																					
LUNAR OCCUP																																					
ORB. RENDEZ																																					
ORB. PR. TRANSF.																																					
HEAVY LIFT																																					
SPACE OP'NS																																					
(UNMANNED)																																					
SCIENTIFIC			✓						✓			✓																						✓			
EARTH OBS.			✓																																		
COMMUNICATIONS			✓	✓					✓			✓																									
NAVIGATION																																					
TELEOP'NS.																																					
(MANNED)																																					
TEST & EXP.																																					
MAINT. & REPR.																																					
CONSTRUCTION																																					
MAT'LS PROCESS																																					

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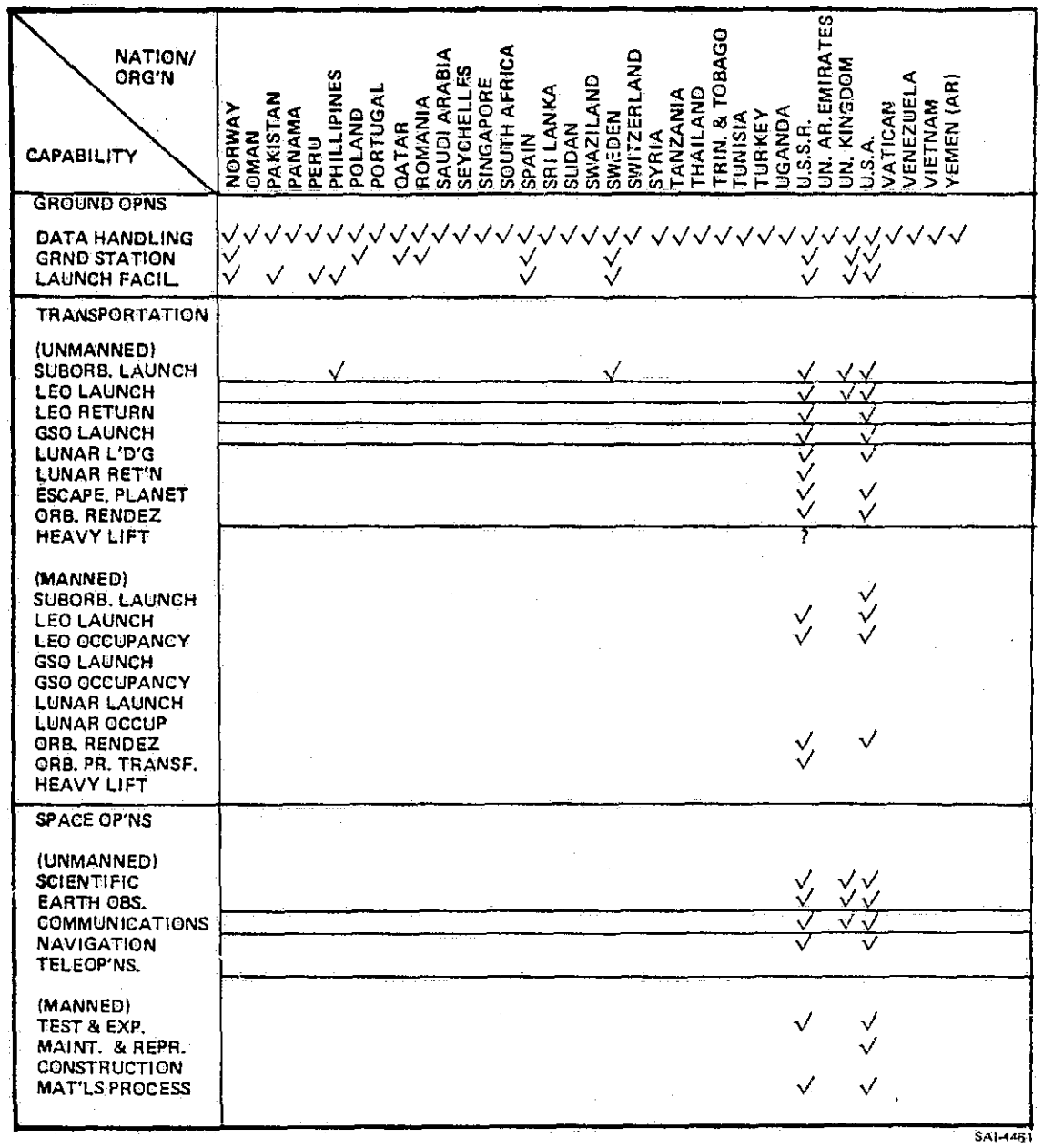


Figure 2-4. (Continued)

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NATION/ ORG'N / CAPABILITY	YUGOSLAVIA ZAIRE ZAMBIA	ESA
GROUND OPNS		
DATA HANDLING	✓ ✓ ✓	✓
GRND STATION		✓
LAUNCH FACIL.		✓
TRANSPORTATION		
(UNMANNED)		
SUBORB. LAUNCH		✓
LEO LAUNCH		✓ ARIANE
LEO RETURN		
GSO LAUNCH		✓
LUNAR L'D'G		
LUNAR RET'N		
ESCAPE, PLANET		✓
ORB. RENDEZ		
HEAVY LIFT		
(MANNED)		
SUBORB. LAUNCH		
LEO LAUNCH		
LEO OCCUPANCY		✓
GSO LAUNCH		
GSO OCCUPANCY		
LUNAR LAUNCH		
LUNAR OCCUP		
ORB. RENDEZ		
ORB. PR. TRANSF.		
HEAVY LIFT		
SPACE OP'NS		
(UNMANNED)		
SCIENTIFIC		✓
EARTH OBS.		✓
COMMUNICATIONS		✓
NAVIGATION		✓
TELEOP'NS.		
(MANNED)		
TEST & EXP.		✓
MAINT. & REPR.		
CONSTRUCTION		
MAT'LS PROCESS		✓

SAI-4462

Figure 2-4. (Continued)

Earth orbit, and four to geosynchronous orbit. Thirteen nations possess and operate their own communication satellites and seven their own Earth-observation satellites. Five can conduct work in space materials processing.

An impressive reality emerges from these observations. Barely twenty years after the first satellite was placed in orbit, much of the world depends on space systems for basic communication, and an increasing number of nations participate in space activity as a means of Earth resource management. It is particularly significant that developing as well as technically advanced nations recognize that space capability and participation in space activities will be a key element in shaping their destinies as nations and as people. This fact must lead to an expanded and intensified awareness throughout the world, of the essentially limitless business and industrial opportunities in space.

From its beginnings, the development of space capability has been multinational in scope. Inspired by the works of Poe, Verne and others, intellectual visionaries in Russia, Germany, France and the United States independently established the theoretical and practical bases for extra-terrestrial systems and operations. These initiatives led to the forming of unofficial rocket experimental groups throughout the industrialized world and eventually to the intensive effort in Germany which produced the V-2 ballistic missile during WWII.

After the war, this German technology was absorbed by the U.S. and the Soviet Union and thus it was that until the early 1960's these two superpowers were the only states having space launch and/or satellite capability. France and the U.K. were also approaching such capability through ballistic missile developments, both having also acquired some V-2 technology.

The internationalist thrust in astronautics had persisted, however In 1950 the International Astronautical Federation was created, an organization of national professional societies and institutions to serve as a form for dissemination of technical and other information on astronautics. Eurospace, an association of European industries interested in the promotion of civilian space projects, was established in 1961. It is comprised of 96 industrial organizations in 11 countries, 31 European banks and insurance companies, 13 corresponding members in the U.S. and one in Israel. Eurospace has provided important stimuli toward an independent European space program, especially as regards launch capability, as well as certain aspects of European-U.S. cooperation.

The true industrialization of space began with the formation of Comsat in 1962, a U.S. publicly/privately-owned coorporation to establish and manage commercial satellite communication systems. Soon after in 1964, the International Telecommunications Satellite Organization (Intelsat) was formed with the U.S. as an initial member. Thus the commercial communcation satellite first proposed in England in 1944, and with it the industrialization of space, became an infant reality on an international basis with the launch by NASA for Comsat, of Intelsat I ("EARLY BIRD") on April 6, 1965.

Since then, Intelsat has grown to include about 100 members and has developed into a model of mutually profitable international cooperation. It has been less successfully emulated by Intersputnik, formed in 1971 by 9 communist bloc nations, using the Soviet Molniya and Stationsionar Satellites. In 1975, the Nordic Satellite Telecommunications Committee was formed comprising the three Scandinavian states, and 1976 saw establishment of the Arab

Satellite Telecommunications Organization of 20 Middle Eastern nations. An agreement to organize an International Maritime Satellite System (Inmarsat) is currently, being negotiated, to include 40 nations.

In addition, there have been and are bi-and multi-lateral agreements to develop and operate communication satellites outside the above organizations. The U.S. and Canada began in 1972 a joint program with the Anik satellites and are continuing with the CTS series. The European Space Agency (ESA) with 10 member nations, is developing and will operate OTS/ECS (1978), Marots (1978) and H-Sat (early 1980s), a heavy communications satellite platform. France, West Germany, India, and Egypt are planning a joint communications satellite program using equipment and technology from the Franco-German Symphonic system, first orbited in 1974. Brazil and France are cooperating on Brazilsat, to be operational in 1979.

Further, unilateral communication satellite systems are appearing with more frequency. India plans Apple and Insat for the early 1980s, Indonesia's Palapal is operational. Iran plans Zorek for 1981, Italy launched Sirio in 1977, and Japan became the third nation after the U.S. and U.S.S.R. to establish successfully a geosynchronous comsat, Kiku II in 1977. Japan is also developing BS and CS (1978) and EC (1980).

Satellites now handle over two-thirds of the world's transocean communications, and this burst of astronautics has resulted in another kind of international cooperation - the multinational consortium. The Symphonic series of satellites was developed and is produced by CIFAS, a group of four French and four German companies formed in 1971. Five

European companies comprise MESH, established in 1976, which won the competition to build the OTS/ECS satellites. Eurosatellite (1977, three European companies) has been selected to develop H-Sat, and Arcomsat (1977, French and German companies) is proposing on Arabsat.

Some of these governmental and commercial organizations are summarized in Table 2-1. Their proliferation since 1960 is depicted in Figure 2-5, which shows that in recent years the growth in the number of commercial groups has accelerated rapidly. Growth profiles in the number of communication satellite launches is shown in Figure 2-6, indicating how Intelsat activity grew on the shoulder of U.S. "pump-priming", and how "other" (largely third-world) activities are currently snowballing. Of course, as implied to the right of Figure 2-6, numbers of satellites are not an index of total communications traffic or business volume, but they do serve as a rough indicator of the growth and proliferation of global interest and commitment

Satellite communications, then, the earliest primary driver toward the industrialization of space, has drawn the commitment of many governments and corporations, and has been and promises to be heavily international in character. The precedent of its success has stimulated similar thrusts in other areas of information handling such as Earth-observation including meteorological observation and Earth-resource identification and monitoring The Soviet Union initiated the Meteor series in 1971 and ESA orbited Meteorsat in 1977. More importantly regarding Earth resources, ESA is establishing Earthnet, a network of ground stations to obtain and utilize data from the Laudsat series, France plans Spot for 1983, India plans SEO for 1978 and Insat for the early 1980s, and Japan plans GMS for 1978.

TABLE 2-1.
SOME EUROPEAN-MIDDLE EAST ORGANIZATIONS AIMED AT SPACE INDUSTRIALIZATION

		FORM. DATE	ORGANIZATION	COMPOSITION	ACTIVITIES
GOVERNMENTAL (INTERNATIONAL)		1964	● INTELSAT	98 NATIONS	INTELSAT SERIES
		1971	● INTERSPUTNIK	9 NATIONS	MOLNIYA (NOT COMPETITIVE YET)
		1975	● ESA (EUROPEAN SPACE AGENCY)	10 NATIONS	MANY (INCL. ARIANE AS SHUTTLE COMPETITOR)
		1975	● NTSC (NORDIC TEL. SAT. COMM.)	3 NATIONS	NORDSAT (ARIANE-LAUNCHED)
		1976	● ASTO (ARAB SAT. TEL. ORG.)	20 NATIONS	ARABSAT
		?	● INMAR SAT (INT'L. MARITIME SAT. SYS.)	40 NATIONS	NOT YET RATIFIED
COMMERCIAL	MULTINATIONAL	1961	● EUROSPACE	96 CO's; 31 BANKS	PROMOTES EURO-SPACE INDEPENDENCE (ESP. LV)
		1971	● CIFAS (CONS. IND. FR-AL. SYMPHONIE)	4 FRENCH CO's 4 FRG. CO's	SYMPHONIE SERIES
		1976	● MESH	5 EURO. CO's	OTS/ECS
		1977	● EUROSATELLITE	3 EURO. CO's	H-SAT
		1977	● ARCOMSAT	2 FRENCH CO's 1 FRG CO	PROPOSING ARABSAT
	NAT'L	1975	● OTRAG (ORBIT. TRANSP. & ROCKET CO.)	FRG. INV.	PRIVATE LAUNCH VEHICLE
		1976	● ANS (SPACELAB UTIL. WKG. GROUP)	3 GERM.CO's	SPACELAB EXPLOITATION

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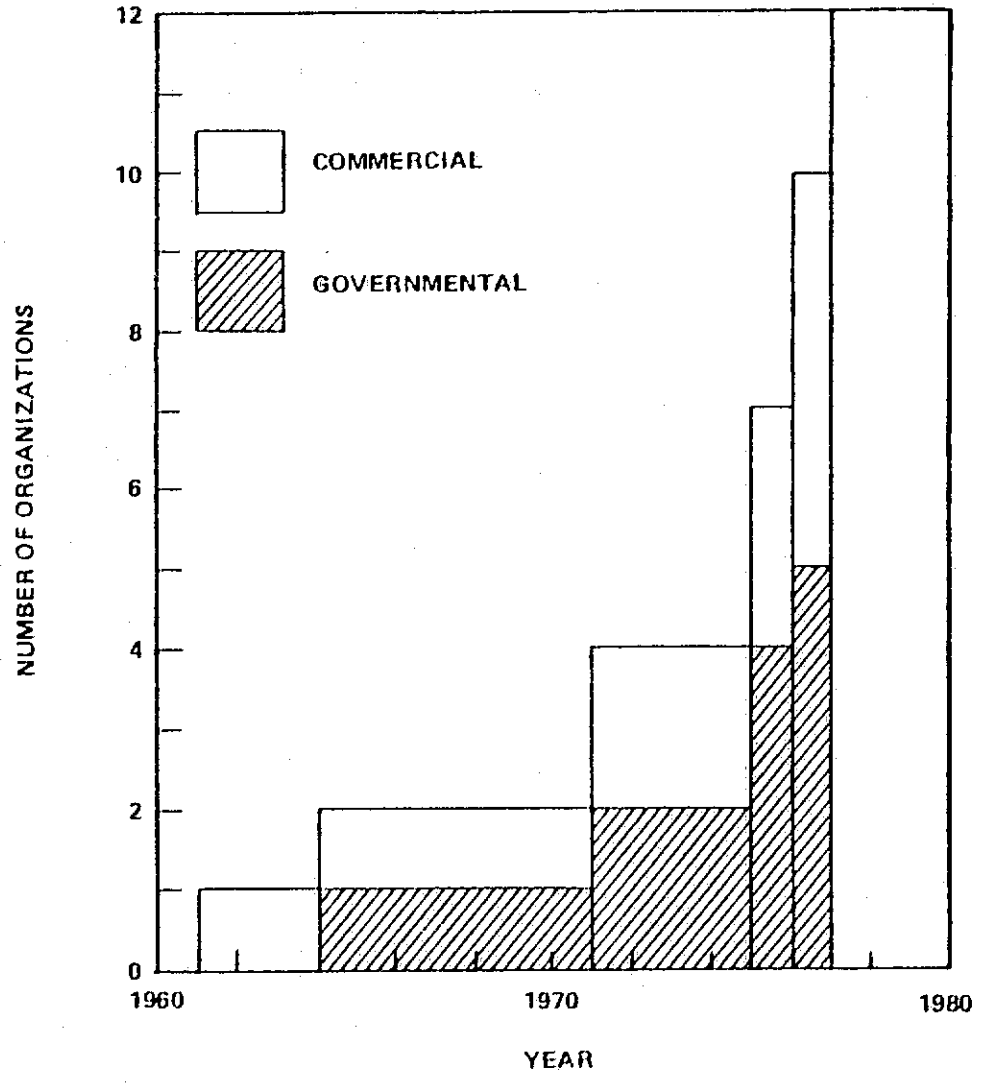


Figure 2-5. Some European-Middle East Organizations Aimed at Space Industrialization

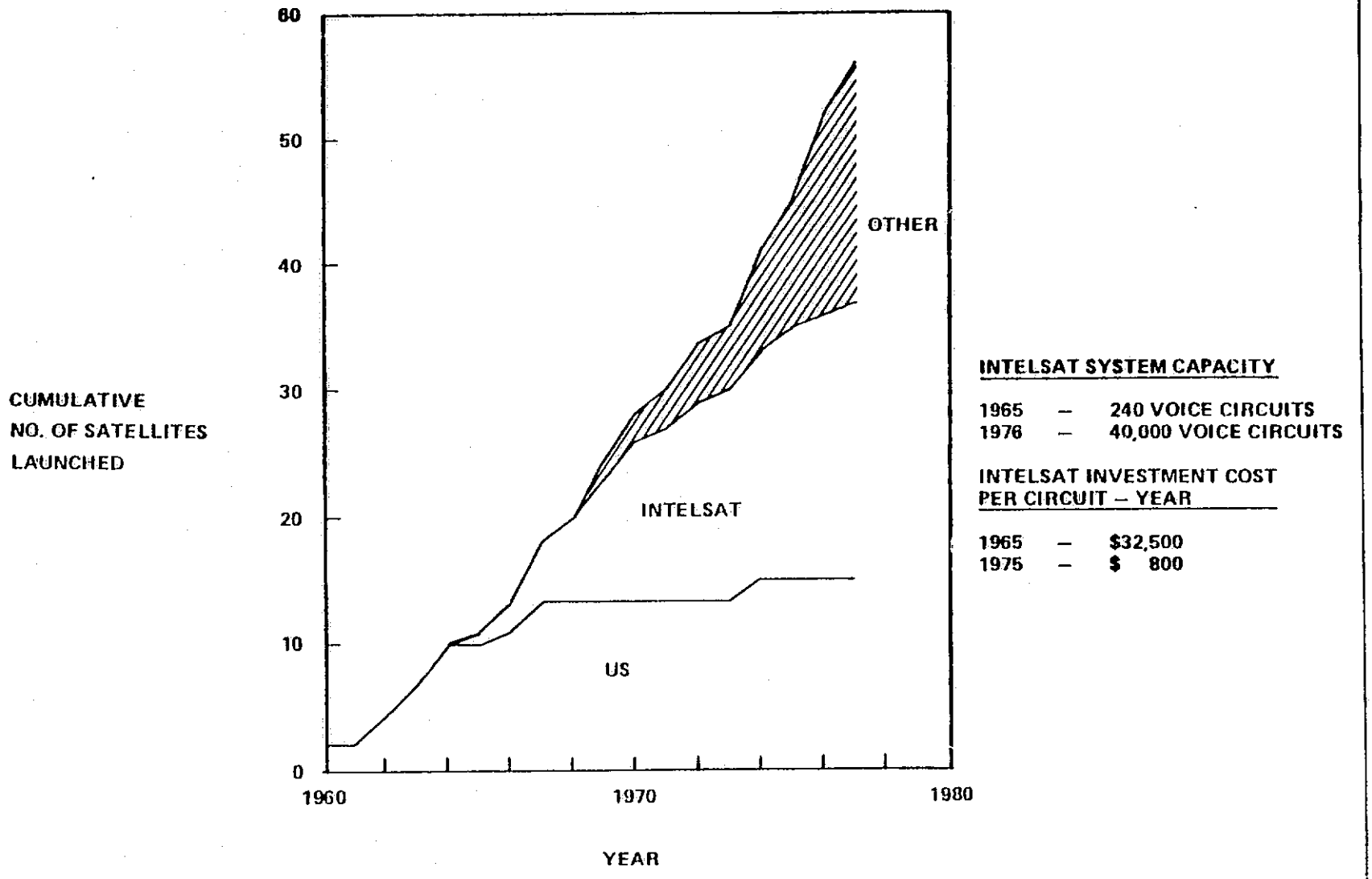


Figure 2-6. Number of Major Communication Satellites Launched vs. Time (Excluding U.S S.R.)

Beyond their commercial benefits, the obvious political and military implications of information handling and observation satellites suggest strong motivations for an ever increasing number of states to acquire them.

After information handling, the next area of space industrialization planned to be investigated on an experimental basis in the space environment is the production of special materials, the processing of which may benefit from the unique features of the space environment. Preliminary experiments have been conducted by the Soviets in Soyuz and Salyut flights, the U.S. in the Skylab and SPAR projects and several European nations in the TEXUS Program. An extensive program of experiments is planned for the early 1980s on the ESA-provided Spacelab, and the Spacelab experimental facilities are to be available to investigators of all nations.

Particular interest in materials research has appeared in West Germany, where in 1976 three corporations formed ANS ("Spacelab Utilization Working Group") to formulate and carry out an organized program of materials processing developments abroad Spacelab, and where the government has established a national payload center to organize the most effective use of Spacelab. It is also speculated in the press that West Germany may purchase a Spacelab for its own use.

Further in the future are possibilities for more extensive information handling facilities, solar power satellites and large habitats for industrial workers and space colonists. All of these require large structures in space, measuring up to many kilometers in extent. Interest in such technologies has been shown by representatives of the Soviet Union, ESA and Japan (as well as the U.S.) at various professional conferences.

A primary key to the industrialization of space is the transportation means for ready and reliable access to and from the space arena, and the more economical the better. Currently only the U.S. and U.S.S.R. possess significant space transportation capability, although France, mainland China and Japan have succeeded in oribiting small satellites and three other nations, Australia, Italy and the U.K. have operational launch facilities. ESA is scheduled to be third in 1979 after the U.S. and U.S.S.R. with its Ariane launch vehicle capable of placing over 900 kg in geosynchronous orbit. Japan is planning an ambitious expansion of its space launch capability during the 1980s, leading perhaps even to an autonomous manned space capability by 1990. A formal governmental recommendation to this effect is now awaiting ministerial action in Toyko. Also, it is speculated that both Brazil and India will develop small orbital launches in the early 1980s. The Chinese Peoples Republic (CPR) has recently announced their intent to initiate a manned space flight program before 1990.

No space transportation system in existance or under development can be called truly economical, relative to terrestrial systems, and while the economics of information handling systems are so favorable that they pay off even with costly expendable launch systems, and while the costly economics of Spacelab can be justified on the basis of its being an experimental and test operation, further industrialization of space must await reduction of transportation costs by at least an order of magnitude. Within the next decade or two, probably only the U.S., U.S.S.R., ESA, Japan and possibly mainland China have the technological potential to do this. Meanwhile, it seems highly likely that there will be competition for launch business at least between the U.S. first generation space shuttle and the ESA Airiane,

which will apparently be competitive with the shuttle in regard to transportation costs on a dedicated launch basis. In fact, it has emerged as an element of ESA policy that Ariane is to be promoted as a competitor with the shuttle for launching Intelsat V and other communications satellites. If shuttle costs rise above guarantees and schedules slip, the Ariane competition could be strong.

Also it should be noted that a sufficiently skilled and funded private group within the industrialized non-communist world might succeed in developing a competitive transportation device on its own. The current OTRAG project in West Germany is an example of such an attempt.

A summary of individual projects for information handling , Earth observation, navigation and transportation is assembled in Table 2-2 for all nations excluding the U.S., U.S.S.R. and mainland China (whose activities and plans are not yet well-known.)

Viewing this background in perspective, one must be impressed by several considerations.

First, the move toward space and especially toward commercial/ industrial activities in space, has in its history a strong international character. Concepts and technologies have been cross-fed many times across the oceans and national boundaries and back to make astronautics practical. The initial industrialization of space, in the communications field, has been predominantly by international cooperation and the first significant steps toward materials processing in space involve a cooperative international program.

Second and in counterpoint to the first consideration, there are strong tendencies toward space-independence within certain geo-political

TABLE 2-2.

SOME CURRENT AND PLANNED INTERNATIONAL SPACE INDUSTRIALIZATION ACTIVITIES
(EXCLUDING USSR, CPR)

ORGANIZATION	SI SYSTEMS			TRANSPORTATION	LAUNCH OR OP'NL DATE
	COMM.	OBSERV.	NAV.		
ASTO (20 NATIONS)	ARABSAT				EARLY '80's
BRAZIL/FRANCE	BRAZILSAT				1979
				POSSIBLE LV	?
CANADA/US	ANIK				1972 ON
	CTS				1976 ON
ESA (10 NATIONS)	OTS/ECS				1978 ON
	MAROTS				1978
	H-SAT				EARLY '80's
		METEOSAT			1977
		EARTHNET*			1977
			AEROSAT?		?
				ARIANE	1979
				SPACE LAB (& POSS. GROWTH)	1980 (1980's)
FRANCE		SPOT			1983
FRANCE/FRG/ INDIA/EGYPT	SYMPHONIE				1974 ON

*GROUND SYSTEMS NETWORK

TABLE 2-2. CONTINUED

ORGANIZATION	SI SYSTEMS			TRANSPORTATION	LAUNCH OR OP'NL DATE
	COMM.	OBSERV.	NAV.		
FRG				POSS. SPACELAB BUY	
				OTRAG	1981
INDIA	APPLE				1980
	INSAT	INSAT			EARLY '80's
		SEO			1978
				SLV-3	1978
INDONESIA	PALAPA				1976 ON
INMARSAT (40 NATIONS?)	INMARSAT				?
INTELSAT (98 NATIONS)	INTELSAT'S				1965 ON
INTERSPUTNIK (9)	MOLNIYA'S				1971 ON
IRAN	POSS. IRANSAT				?
ITALY	SIRIO				1977
JAPAN	KIKU II				1977
	BS				1978
	CS				1978
	ECS				1980
		GMS			1977
				N SERIES	1975 ON
				(POSS. MANNED PROGRAM)	1990
NTSC (3 NATIONS)					EARLY 80's

spheres and space-competitiveness between spheres. The spheres which seem to be emerging are the U.S., Europe, U.S.S.R., mainland China and Japan.

Third, each of the above spheres has the technological potential to develop within a decade or two an effective and autonomous space transportation capability which will open to it the resources and environment of space for an advanced phase of technical and industrial development.

In the drive for extraterrestrial benefits, alliances between spheres except as temporary expedients might seem unlikely, although in each case relationships might be sought with less-developed "terrestrial" nations on account of geography or resources. In fact, increasing awareness is actively manifest among nations at all levels of development, of the importance to their own destinies of seeking the benefits of space activities, either on their own or with stronger partners. As of September 1977, 146 nations reported space-related activities, 126 non-launcher nations had 354 international space memberships, 35 had cooperative space programs and 21 had 78 bi-lateral programs.

In view of this, as each major sphere acquires the transportation knowhow, the affairs of Earth may be expected to be extended to space including the complex counterpoint: cooperation where necessary and/or mutually beneficial and competition where possible and unilaterally beneficial.

Such a future seems far more likely than the utopian one of universal cooperation and brotherhood, or the gloomy one of some kind of catastrophe or despair, and it poses a host of procedural and institutional issues and challenges, both on an international scale and domestically for U.S. government and the private sector.

Why is there such extensive involvement in organizing for and implementing space industrialization in the world? In the simplest terms, it appears that needs and markets exist forming the basis for large scale international involvements as illustrated by Figure 2-7. This has prompted a wide spread interest and desire for independent capabilities to utilize space and an awareness of the potential benefits from gaining and maintaining a competitive position. In the free world the US will be challenged through the eighties in all technologies including those that are peculiar to manned space flight. The recent capability demonstrations of the USSR aboard Salyut 6 and the strong reports of their current development of a reusable shuttle leave no doubt that major technical achievements can be anticipated by communist bloc countries in SI throughout the eighties.

2.2 POTENTIAL WORLD IMPLICATIONS

Will Space Industrialization prove to be a boon or a bane for the world? Every decision maker would like to know the answer to such questions which ultimately form the basis for deciding whether or not to proceed with specific activities or programs. Yet such a question can never be answered objectively and universally, even long after a program has been fully implemented. Every human being will arrive at a different evaluation of any given program on the basis of personal values, and the answer may even differ for the same individual from one moment to the next.*

* The federal Interstate Highway system in the United States is a case in point. The system has taken several decades to complete at a cost of tens of billions of dollars. Was it good or bad for the U.S.? For the middle class, it increased personal and family mobility enormously, allowing convenient access at moderate cost both to the job opportunities and cultural benefits of urban life as well as to the less-crowded, partly rural lifestyle of the suburbs. Simultaneously it made the new suburbanites dependent on the automobile, and the commuting suburbanite may curse the Interstate Highways vehemently during traffic jams on the way to or from work. While more people have been able to visit the National Parks, Forests, Wildernesses, and Monuments, broadening political support for expansion of these systems, they have also brought pollution and land degradation to these preserves, leaving ardent environmentalists with mixed feelings about the Interstate Highways.

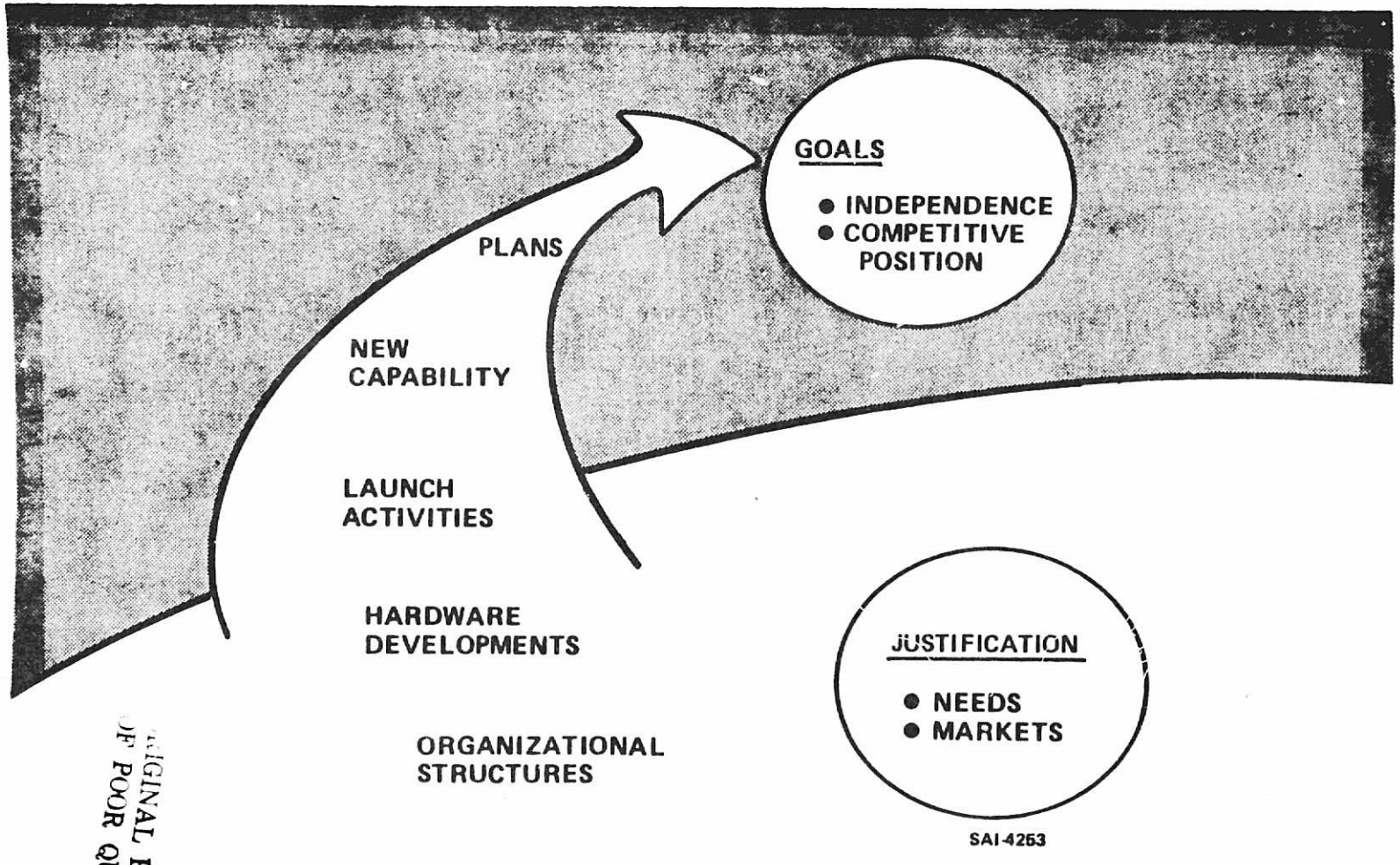


Figure 2-7. Evolution of World SI Activities

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Although it may be impossible to answer the question asked above, we can provide some assessments of the consequences of Space Industrialization, and these assessments provide some of the information needed to weigh the consequences against our personal sets of values; to be useful, such assessments must go far beyond mere economic analysis of costs and benefits. "Impact assessment" thus provides an educated basis for personal judgments; it is no substitute for those judgments.

But impact assessment has another aspect which is perhaps more important. Properly used, impact assessment is an integral part of an *iterative design process*. Suppose we agree to a certain set of values and we decide to design a system which will provide certain products and services which we consider, in the light of our values, to be highly desirable and beneficial. Impact assessment is then a valuable tool in designing the system to provide the greatest possible benefits while minimizing undesirable side effects. In this approach, an initial system design is examined to see how well it meets the design goals and to identify possible adverse side effects by simulation, by prototype testing, or by careful and imaginative analysis. The design is then modified to improve its performance and to reduce undesirable side effects, and the entire process repeated until the design modifications on each iteration become very small.

In the present discussion of Space Industrialization, we cannot attempt a comprehensive impact assessment for the entire family of Space Industrialization programs over the next three decades. Because of the importance of impact assessment as a design tool, it must be applied (in the first iterations) to specific products or services provided to specific markets. The terrestrial socioeconomic system today may be viewed as a collection of more than 150 sovereign states, a few dozen protectorates and territories recognized by international agreements, a few dozen international treaty organizations, several hundred multinational corporations, and a few transnational organizations such as the World Council of Churches and the Roman Catholic Church. The disparity and diversity of economic, political, societal, technological, military, and environmental conditions among these make it impossible to assess the impacts of semiconductors manufactured in orbit, for example, on the world as a whole. Likewise, as we shall see,

Solar Power Satellites cannot be designed as a single homogeneous system if they are to succeed in Third World and Fourth World countries as well as in the Western industrialized nations. (If there is no market for a specific product or service of space industries, there will be no benefits either, unless the benefits are very indirect.)

Accordingly, we have attempted to provide a preliminary guide to impact assessment by examining the relevance of a number of products and services which may be provided by space industries to a few less-developed nations. No major differences should be expected between impacts in the United States and in the more affluent Western nations such as Canada, Sweden, West Germany, Switzerland, France, and the industrialized parts of Spain and Italy. Political factors make it very difficult if not impossible to assess the possible impacts of space industries on the centrally planned economies of Eastern Europe and Asia. We have thus focussed our attention on the Third and Fourth World countries which are not tightly aligned with the centrally planned economies. This preliminary examination should suggest areas of Space Industrialization which are most likely to have extensive foreign markets and to indicate which markets should be studied in greater depth.

In addition to this examination of products and services versus distinct market regions, we have outlined a host of purely environmental questions which must be examined for each space industry or major facility. In our present state of ignorance about conventional sources of pollution and environmental degradation, we can do little more than indicate issues and questions related to the more exotic industries yet to come. In this area, too, we must emphasize the importance of impact assessment as an iterative design tool; it is not enough to design a system optimized purely by economic and technological standards and to then write an Environmental Impact Statement. Consideration of the environmental impacts must proceed hand-in-hand with the design process itself if Space Industrialization is to realize its full potential for the benefit of humanity.

We have chosen Indonesia, Niger, India, and Brazil as representative countries, spanning a fair range of income per capita, climatic and

environmental factors, and population densities, while also representing Oceania, Africa, Asia, and South America. Information used in developing these preliminary impact assessments was based on the official government proposals for development assistance from the United Nations Development Program and on commonly available information in encyclopedic and almanac sources.

Although these assessments are preliminary and necessarily crude, they do serve to indicate the necessity for individual marketing region assessments and the need for iterative design to adapt the services or products to each market.

2.2.1 Indonesia

2.2.1.1 Geography

Indonesia consists of more than 3,000 islands straddling the equator between Southeast Asia and Australia, extending 5,120 kilometers. The five largest pieces of Indonesian territory are the islands Sumatra, Java, and Sulawesi (formerly Celebes), and portions of two other large islands, Kalimantan (sharing the island formerly known as Borneo with two provinces of Malaysia and with the British dependency Brunei) and Irian Jaya (sharing the island New Guinea with the Australian Territory of New Guinea and Papua New Guinea, an Australian protectorate until 1973). Irian Jaya was ceded to Indonesia in 1963, having been the Netherlands New Guinea, under the name West Irian; the name was changed to Irian Jaya in 1973.

The climate of Indonesia is typical of tropical islands, with heavy rainfall and high humidity. Total land area is about 1,900,000 square kilometers (733,600 square miles). As of 1973, some 15% of the land was devoted to agricultural uses and about 20% was covered by forests, some of them in commercial timber production.

2.2.1.2 Population

The 1973 population of Indonesia (according to U.N. estimates) was about 124 million, with a growth rate of 2.5% per year. Average population density was then 65 per square kilometer (168 per square mile). More than 80 million live on the island of Java, where population density averages

600 per square kilometer. The government is actively promoting transmigration from Java to Sumatra and Sulawesi, with incentives for settlers in the form of food staples in exchange for labor on development projects such as road construction. More than 80% of the total population is rural.

2.2.1.3 Economic Factors

Gross domestic product in 1972 was about $10 billion (U.S.) or about $80 per capita per year. Indonesia has enjoyed a favorable trade balance, with $7.4 billion worth of exports in 1974 versus only $3.8 billion of imports. Petroleum exports accounted for more than half of the export earnings, with large contributions from agricultural products and timber as well. Transportation and telecommunications are generally of insufficient capacity, especially in view of Indonesia's geography. Agriculture provides about half of the gross domestic product, while industry accounts for about 10%.

2.2.1.4 Societal Factors

Overall literacy is only 50 to 60%; less than 40% of children entering first grade complete sixth grade. Although much of Indonesia (especially Java) had an extensive entrepreneurial class prior to colonization by the Netherlands, natives were systematically excluded from managerial positions during the colonial period. Even today there is a severe shortage of skilled workers at the planning, administrative, and managerial levels. Rural areas generally lack adequate medical care and adequate clean water supplies. Urban areas suffer from poor housing and sanitation facilities.

2.2.1.5 Political Factors

Indonesia became an independent sovereign state in December 1949 with Ahmed Sukarno as President. Beginning in 1963, Sukarno engaged in a guerrilla war attempting to prevent the formation of the Federation of Malaysia in neighboring territories while encouraging Communist influence at home. Early in 1966, Moslem students began a vigorous anti-Communist movement which resulted in a populist purge of more than 300,000 Indonesians suspected of Communist ties. Sukarno, who had been elected President for life, was forced to relinquish his powers to the Army chief of staff,

General Suharto, in March. Suharto ended hostilities with Malaysia with the signing of a treaty in August 1966, reestablished national elections, and developed closer ties with the Western democracies. Sukarno was forced to resign his title as President in March 1967 and General Suharto assumed the position of Acting President until he was elected President one year later for a five-year term by the Consultative Assembly. In 1973, he was reelected for a second five-year term, without opposition. Following the collapse of Cambodia and South Vietnam in 1975, Suharto has pursued a course of non-alignment with any major power. Overall, political conditions seem relatively stable for the foreseeable future, although there is some agitation in the Molluccan Islands for greater autonomy or even independence. The general stability has been reflected by substantial foreign investments since the institution of the first Five Year Plan in 1969. Gross Domestic Product during the 1969 to 1973 period grew at an annual rate of 6 to 7%, while export earnings grew at a rate of 15% per year.

2.2.1.6 Potential Markets for Space Industrialization

Several areas of Space Industrialization can be expected to find markets in Indonesia. These include communications satellites, Earth resources satellites, ocean resources satellites, and weather satellites. Because of Indonesia's extensive petroleum reserves and relatively low energy consumption per capita, little need for energy from space can be foreseen. Given Indonesia's equatorial position, however, space transportation services could become important in the Indonesian economy during the 1980's or 1990's. (The government of Indonesia has expressed interest in the concept of an international civilian launch site with free trade zone status in a formal letter to the Sabre Foundation's Earthport Project.) These areas will be discussed below.

2.2.1.7 Communications Satellites

The geography of Indonesia poses serious problems for telecommunications, a basic component of the economic infrastructure needed for development programs and for the expansion of commerce. Per capita income of $80 per year (growing to perhaps $200 per year by the late 1980's) suggests that personal communications via satellite (as well as conventional

telephones) will be restricted to commerce, industry, and government agencies, with little penetration of the general population for personal use except in a system analogous to public payphones. While domestic industry and commerce would certainly benefit from wider access to efficient telecommunications services, the largest effect would be expected in imports and exports, where satellite communications would provide global capabilities as an inexpensive spin-off of the domestic system. Rapid negotiations of prices should serve to improve Indonesia's bargaining position relative to present conditions.

The Indonesian government is already engaged in the development of a national library and documentation system to assist in the development of domestic scientific and technological capabilities as well as in the development of the entire educational system. A National Information Service may well be profitable as a governmentally subsidized program in Indonesia.

Public adult education by direct broadcast to village television sets could be aimed at improvements in public health and sanitation to improve productivity of the laboring force, at improvements in agricultural productivity through rapid introduction of new techniques requiring little capital investment, and at improving adult literacy.

The availability of inexpensive telecommunications by "payphone" would provide some human benefits as well, permitting families who have resettled into newly developed areas to keep in closer touch with friends and relatives left behind. Such a system, if designed to receive broadcast signals as well as discrete channel signals, could also serve as a nationwide emergency warning and relief system, providing early warning of severe weather conditions and coordination of earthquake relief.

2.2.1.8 Earth Resources Satellites/Ocean Resources Satellites

Present governmental programs in transmigration; development of new agricultural areas in Sumatra, Sulawesi, and Irian Jaya; development of commercial timber in Irian Jaya; the search for safe water supplies; surveys for expanded and new harbors, both for inter-island shipping and for export shipping; and construction of roads, railroads, and highways can all

benefit from satellite surveys using multiple spectral band photography. The most important considerations in system design here are matching available spectral capabilities to the end uses of the photographic surveys and reducing the time required for processing and analysis of images to a minimum.

Minerals prospecting (both on and offshore) by satellite would allow rational development of mining and drilling leases and grants by foreign investors and by the governmentally operated petroleum industry, further improving Indonesia's trade balance and ability to purchase.

Fisheries presently contribute modestly to Indonesia's food supply (especially in animal protein) and would likely improve annual yields consistent with sustainable yields with up-to-date information on ocean conditions.

2.2.1.9 Weather Satellites

The development of new agricultural areas and of new water supplies for agriculture, for people, and for industry requires an extensive data base on weather conditions (especially precipitation patterns) throughout the Indonesian islands. Weather satellites can provide this information more rapidly and economically than available alternatives, especially given the difficulties of training a corps of thousands of weather observers in the absence of an adequate school system. Such satellites may also provide some benefits to shipping which is so vital to the Indonesian economy.

2.2.1.10 Space Transportation Ground Facilities

The advantages of equatorial launch sites are well known to rocketeers. These include increased payload for a given vehicle at a given launch azimuth for a given orbital altitude; unlimited launch and reentry windows to and from equatorial orbits; and easier access to geosynchronous orbit, lunar orbit plane, and ecliptic plane trajectories than is possible from high latitude launch sites such as Cape Canaveral or Vandenberg Air Force Base.

A variety of locations in Indonesia would provide suitable launch and landing sites. Sulawesi, Sumatra, and Kalimantan (all lying directly astride the equator) have extensive areas as yet very sparsely

populated, including highlands rising to more than 5,000 feet above sea level at moderate distances from potential harbor sites, providing the additional benefit of placing the launch site above some 15% of the Earth's atmosphere. Irian Jaya offers similar conditions within 1^0 of the equator; several of the Molluccan Islands are also possibilities, although they lack the highlands of the larger islands.

The development of an international launch and recovery site would provide a new source of foreign exchange; increased tourism from abroad; new employment opportunities; stimulus for higher education and the development of indigenous technological and scientific capabilities; and would provide the basic infrastructure (roads, communications, harbors) for the development of a sparsely populated area, with relatively little investment by Indonesia itself.

2.2.1.11 Other Areas

Because the Indonesian industries form a relatively small (but growing) sector of the economy, and because they generally do not use very high levels of technology, it is unlikely that Indonesia will have significant market potential for products manufactured in orbit until development toward extensive industrialization has occurred. For similar reasons, Indonesia is unlikely to be directly involved in space facilities or hardware, although its geographic location is ideal for ground facilities. Energy from space shows little relevance until, perhaps, after the turn of the century when per capita income and per capita energy consumption have risen substantially.

2.2.2 Niger

2.2.2.1 Geography

The Republic of the Niger was formerly part of French West Africa. Covering 1,267,000 square kilometers (489,190 square miles), it is completely landlocked. On the north, it is bordered by the Saharan regions of Algeria and Libya; on the east, by Chad and Lake Chad; on the south, by Nigeria and Dahomey; on the west, by Upper Volta and Mali. The climate is among the hottest in Africa. Most of the country is flat, with numerous depressions, and one mountain range, the Air range, in the

central northern part of the territory. Most of the country is part of the Sahara; the southern part of the country is Sahelian; while the extreme southwest has a Sudanian climate. Most of the country has less than 350 mm of rainfall annually, below the limit for cultivation, although in the Sudanian region, rainfall exceeds 600 mm per year. The Niger River traverses several hundred kilometers of near-desert in the southwestern portion of the country, providing the only waterway to the ocean through Nigeria.

2.2.2.2 Population

The population of Niger in 1973 was about 4.3 million people, fewer than 10% of whom lived in urban areas. In the Sahelian and Saharan regions, much of the population is nomadic. Population growth rate early in the 1970's was about 2.7% per year. Overall population density was only 3.1 people per square kilometer (about 8 per square mile).

2.2.2.3 Economic Conditions

The Gross Domestic Product in 1971 was about $400 million (U.S.) or about $100 per capita per year. Imports amounted to about $60 million, with only about $42 million in exports. About 40% of the exports were groundnuts (shelled, crude oil, oilcake). Livestock products (meat, hides and skins) contributed another 23%. Other export products include cotton, cereals, cowpeas, onions, fish and uranium. Imports include transport equipment (motor vehicles, tractors, cycles, spare parts), petroleum products, machinery, chemicals, miscellaneous food and beverage products, cotton textiles, and tobacco and matches.

A series of national development plans since independence have stressed the following objectives:

(1) Development of the rural sector, with first priority to food crops for domestic consumption, and lower priority for improvements in cash crops and stock raising.

(2) Development of water resources for human, agricultural, and pastoral needs.

(3) Intensification of mineral and petroleum prospecting. Under governmental instigation, a uranium deposit with reserves of some 20,000 tons was discovered in 1967, with more than 860 tons of uranium metal produced by 1972. Three deposits of tin were already in production in 1972, and additional prospecting activities showed promise of copper, molybdenum and copper, nickel, and another uranium deposit. Phosphate and iron ore may also be available, and a deposit of 4.5 million tons of coal has been located in test drillings.

(4) Development of the road infrastructure and of communications routes with other countries. A total of 1,236 kilometers of dirt roads and 554 kilometers of asphalted roads were constructed up to 1973 following independence in 1960. An additional 1,280 kilometers were planned for construction by 1975. International telecommunications connections have been a major target for reinforcement and expansion.

(5) Government policy has been aimed at lowering the cost of energy as rapidly as possible.

(6) Development of trade and industry along lines of emphasizing national products rather than imports.

(7) Development of the educational system along lines appropriate to Niger's present state of development. Although 22% of all government expenditures (both national and local) go to education, results up to 1973 were disappointing, providing too few graduates to fill even low-level positions in government and industry, and inadequate capacity for the growing population.

2.2.2.4 Societal Factors

As yet, Niger has had to rely on foreigners (principally French) to staff managerial positions throughout the government and industry. Inadequate planning in the late colonial period and the early years of independence resulted in an extensive program of tube-well drilling and construction which disrupted the pastoral tribes whose livestock were concentrated around the new oases and were much more susceptible to the ill effects of the Sahel drought of the early 1970's than under earlier, more dispersed conditions. Illiteracy is high, and urban job opportunities are as yet very limited.

2.2.2.5 Potential Markets for Space Industrialization

Because of the small population of the Niger (only 7 to 8 million by 2000), the total market will be quite limited for space industrialization products and services. Nonetheless, some of these services may provide very important contributions toward economic development of the area. Principal areas of interest are communcations satellites, Earth resources satellites, perhaps weather satellites, sensor polling satellites, and (possibly) solar power satellites. Low income per capita will severely restrict demand or applicability of materials processed in space and make people-in-space activities (research and higher education, tourism, medical services) irrelevant. The moderate geographical latitudes of the country (from 12^0 N to 23.5^0 N) do not provide sufficient incentive for possible launch facilities in the face of its relative inaccessibility in the continental interior.

2.2.2.6 Communications and Sensor Polling Satellites

The vastness of the country and its low population density pose major difficulties for the development of adequate communications infrastructures. Satellite telephone circuits have already proven their cost-effectiveness for business and government around the world; continued reductions in the cost of ground stations will accelerate efficient communications in the Niger and allow more effective participation of the country in global trade, especially as the mineral resources presently unknown are discovered and exploited. Nomadic pastoralists will have little use for satellite communications; sedentary villagers will have insufficient income to afford personal communications services, although local businesses and government offices may find public "payphones" useful and affordable. Large cash crop farmers may find such services invaluable in speeding up access to replacement parts for agricultural machinery including tractors.

Mass public education may benefit from direct broadcast TV capability, allowing a limited number of qualified teachers to be utilized more efficiently in such a sparsely settled country, making it possible to present newly developed curricula in native languages more economically than might otherwise be possible. Adult education in public health matters,

agricultural techniques, and basic literacy may also use the same facilities installed in central locations in larger villages.

A major obstacle at present to obtaining investment capital for the development of new agricultural areas is the lack of data on rainfall across the country. Remote sensors polled by satellite may prove to be the most effective solution to this problem.

2.2.2.7 Earth Resources Satellites

Earth resources satellites would be of great benefit in the search for mineral deposits across such a vast area. Of particular interest would be groundwater supplies, petroleum, and phosphate. Such satellites would be of little value in mapping the countryside for the development of roads and highways because of the predominantly flat terrain, but some applications for the placement of water catchment facilities may be found. Rapid geological prospecting by satellite would have strongly positive impacts on trade balance, employment, infrastructure development, and development of modern mining and industrialization. Because of the scarcity of indigenous geologists, such surveys would not displace trained personnel. A final use of such satellites would be to assist in the implementation of reforestation programs which are urgently needed to halt (or even reverse) the encroachment of the Sahara into the Sahelian zone.

2.2.2.8 Energy

The principal source of energy for the rural population for cooking and heating (nights can be quite chilly) is firewood whose use has accelerated the encroachment of the Sahara and aggravated the effects of the Sahel drought in the early 1970's. Imported petroleum products are far too expensive and are difficult to deliver into the rural areas. Liquid fuels (such as methanol) could be synthesized from electricity provided from a solar power satellite, but the difficulties of transporting the liquid fuels or of extending power transmission lines from a rectenna out to regional synthesis plants seem formidable. Shortages of water in many areas (to be used in methanol synthesis) further limit the viability

of this idea. Should deforestation progress too far, however, and should the petroleum and coal deposits hoped for prove to be too expensive, there may be no other alternatives for domestic energy supply. One solar power satellite of 10 GW capacity would suffice for the domestic energy needs of Niger's population past the turn of the century.

2.2.3 India

2.2.3.1 Geography

Extending from 37°N to 8° N in latitude, India spans tropical, subtropical, and temperate climatic zones, with near-Arctic conditions in the higher Himalayan foothills in the north. With a total land area of 3,288,000 square kilometers (1,266,600 square miles), it is the fourth largest country in the world in area. The Indo-Ganetic plain, extending from the Bay of Bengal on the east across the country to the Afghan frontier and the Arabian Sea on the west, is the richest and most densely settled region of the country. Much of the southern portion of the subcontinent is occupied by the Deccan Plateau, with elevations between 2,000 and 3,000 feet above sea level. The Indus River (originating in Tibet) passes through the northwestern portion of India for a short distance before entering Pakistan through which it flows into the Arabian Sea. The sacred Ganges River arises in the Himalayas northwest of Nepal, flows south into the northern plain before turning generally eastward for about 1,500 kilometers to the Ganges delta which extends some 220 kilometers inland from the Bay of Bengal. Most of the delta lies within Bangladesh (formerly East Pakistan). The Brahmaputra originates in Tibet, flows eastward through the northeastern regions of India, then turning south into Bangladesh where it joins the Ganges delta. These three rivers are all very seasonal, depending on the monsoons which feed their tributaries in the Indo-Gangetic plain and on the Himalayan snowpack deposited by the monsoons.

In such a vast subcontinent, it is not surprising that a great deal of mineral wealth is already known, including iron ore, diamonds, uranium, silver, gypsum, tungsten, zircon, and sapphires. Significant oil production is underway in Assam and in Punjab, while major coal fields

are being worked in Bihar. Most of the country, however, is as yet inadequately prospected.

2.2.3.2 Population

India's population in 1973 was approximately 575 million, and is anticipated to reach 1100 million by the year 2000. About 80% of the population is rural, living in some 600,000 villages averaging fewer than 1,000 inhabitants each. More than half the villages have fewer than 500 inhabitants. Although Hindi is the official language, at least 14 other languages are used by populations of 10 million or more. Cultural differences across the country are marked. Some 83.5% of the population is Hindu (with numerous sects), and an additional 10.7% are Moslem. Christians, Sikhs, and others make up the remaining 5.8%. The Ganges basin, having only one-fourth the land area of the country, has somewhat more than one-third of the total population.

2.2.3.3 Economic Factors

Economic statistics for India are difficult to gather. The 1974 Gross Domestic Product is estimated to be about $90 billion (U.S.) or about $160 per capita per year. Imports in 1974 totalled about $4.97 billion, while exports were only $3.91 billion. India has suffered chronically from trade deficits, resulting in very large debts to foreign governments and banks. Agriculture still dominates the Gross Domestic Product, although the government has very deliberately encouraged the development of modern industries in the major cities with perhaps too little attention to rural development. Land ownership is generally very concentrated, with widespread rural unemployment contributing to the rampant growth of slums around the cities.

While railroads are fairly extensive on the subcontinent, much of the equipment is antiquated, and vast rural areas have little transportation service available. Roads are inadequate for the development of extensive economic trade between the countryside and the cities or between the hinterlands and overseas markets. Communications services are largely nonexistent for the villages.

2.2.3.4 Societal Factors

India's cultural diversity has hampered national development in many instances. Although the Hindu caste system was outlawed when India achieved independence in 1949, Untouchables are still widely discriminated against and remain the poorest of the poor. Illiteracy is widespread, sanitation is generally poor, and such diseases as cholera and typhus are still endemic. Higher education is available to a small fraction of the population, for whom it represents a means of entry into the governmental bureaucracy with significant economic security. The "brain drain" is a major problem, especially in the sciences and in medicine. The immigrants into the cities seldom find jobs in the monetized economy, eking out a living by providing services to each other.

2.2.3.5 Political Factors

Although India's constitution is that of a parlimentary republic, a major perturbation occurred during 1975 and 1976, when Indira Gandhi declared a state-of-emergency following her conviction for election law violations. Constitutional guarantees were suspended, and numerous political opponents and press critics were imprisoned. During this same period, Mrs. Gandhi's administration initiated a compulsory sterilization program in some of India's states, which had wide abuses due (in part) to its quota system. These factors resulted in the downfall of the Congress Party in the elections of March 1976, ending the total domination of Indian politics since independence by that party. Ineffective development strategies and political corruption have continually resulted in widespread dissatisfaction although the population in general is sufficiently apolitical that little outright unrest or violence has resulted.

Foreign prestige considerations have often seemed to be of greater importance in governmental policy for economic and technological development than have the needs of the population. India joined the nuclear weapons club in May 1974 with the testing of a nuclear explosive using plutonium diverted from a nuclear power reactor supplied by Canada with insufficient safeguards against such use. The current government,

however, has disavowed its intention to further develop nuclear explosives for either military or peaceful purposes. The Indian government has officially remained non-aligned with either the Western or the Eastern blocs, but signed a 15-year cooperation agreement with the Soviet Union in 1973 for economic, technological, and trade cooperation, including a commitment by the Soviets to build up to 90 heavy-industry projects.

2.2.3.6 Potential Markets for Space Industrialization

Principal markets for Space Industrialization in India appear to be communications satellites, Earth resources and weather satellites, and Solar Power and night illumination satellites. Little market can be foreseen for materials processing applications during the next decade or two, until personal incomes have rise appreciably.

2.2.3.7 Communications Satellites

A variety of communications satellites would be beneficial to India in its economic development programs because of its large areas and tiny villages. Public "payphones" would be more likely to succeed than would portable telephones, largely because of the low level of personal income. Direct broadcast television offers major promise (as shown in the ATS experiments in India) for the dissemination of agricultural education, public health education, and for warnings of imminent storms or floods. Widespread broadcast of forecast dates for the arrival of the monsoon would be of major benefit to farmers, allowing them to optimize timing of plowing and transplantation of rice seedlings, for example. Literacy would also benefit, particularly with programming provided in each of the 15 major languages of the country.

2.2.3.8 Earth Resources and Weather Satellites

Prospecting for new mineral sources, assessing crop inventories early in the growing season, and providing accurate cartographic information for the construction of roads, dams, and water catchment facilities would all make important contributions to economic development for India. Such projects could be financed by international organizations (such as United Nations Development Program or the World Bank) or by the Indian government itself. Design of these programs must take into account the



government's desire to avoid disheartening its own cadres of highly educated experts in geology, engineering, etc., who might feel that satellite programs made them obsolete at home.

Weather satellites are important principally because of agriculture's dependence on the monsoon and because of India's vulnerability to typhoons and floods.

2.2.3.9 Solar Power Satellites and Night Illumination Satellites

Energy looms large among India's developmental problems. For the rural population, the principal sources of energy are cattle dung, firewood, and other biomass sources. With per capita energy consumption (just for cooking) averaging one ton of firewood per year, total deforestation is expected by 1997, with severe adverse impacts resulting from greater runoff of rains, enhanced erosion, increased flooding of prime agricultural lands, and greater silting of the rivers. Domestic oil and gas reserves are expected to be depleted by 1995 (although this is subject to change should a major Earth resources satellite program be implemented). Low grade coal is available in large quantities but cannot be distributed conveniently throughout the rural areas and has severe environmental difficulties.

Solar power satellites may be a viable option here; we shall discuss this case in greater detail than other items in order to illustrate how impact assessment goes hand-in-hand with iterative system design.

The SPS as presently designed has been geared to the delivery of electrical power to the ground. Suppose we set out to use solar power satellites in this manner in India. It is impossible to electrify the 600,000 villages of India in less than one or two generations, well beyond the time-scale of this study. Thus SPS for electricity would be applicable only to the cities where electrification already exists or could be installed in reasonable times because of the high density of potential users. What effect would this have?

First, few city inhabitants could afford to buy enough electrical appliances to make significant use of electricity beyond lighting (if they

could afford lighting fixtures). Factories would thus be the principal users of SPS electricity, and heavy industries would certainly benefit. Expansion of the benefits of SPS for the Indian economy would depend strongly then on expansion of heavy industry, which is characterized by capital investments of several thousand dollars per job created. (Each workplace created would thus cost tens or hundreds of man-years of wages at the Indian national average of $150 GDP per capita per year.) This would result in little expansion of employment accompanied by a major drain on scarce capital funding.

Can SPS be better used in India? Remembering that 80% of the population is rural, and that the existing infrastructure for energy involves short-distance transportation of dung and firewood by human or animal back or by such vehicles as bicycles and oxcarts, the need is clearly for liquid or solid fuels, not for electricity. Methanol (wood alcohol) is such a fuel which can be burned efficiently in small, simple stoves which could be mass-produced for a few dollars each. (Stoves burning firewood or cow dung presently deliver only about 9% of the chemical energy content of the fuel into the cooking utensils, versus about 36% for natural gas and electric stoves in the United States.) Approximately 400 kilograms of methanol per year (about half a gallon a day) would replace the ton of firewood presently required per person for cooking, without any credit for the improved efficiency of the methanol stoves. Assuming that about 50% of the electrical energy could be converted into chemical energy in methanol by direct synthesis from water and carbon dioxide, one SPS of 10 Gigawatt capacity could supply methanol for 16 million people's cooking needs. Thus 75 SPS installations of 10 GW capacity would suffice for most of India's rural energy needs in the year 2000. Distributing electricity (DC) from the receiver antenna sites to some 1200 methanol synthesis plants, with an average electrical transmission distance of 50 kilometers, the average distance for transportation of methanol to the customer would be 25 kilometers, comparable to distances over which firewood is presently transported. Each methanol synthesis plant would then produce some 1,100 metric tons of liquid fuel daily, using only air and water as raw materials. (The CO_2 would be obtained either by cryogenic techniques or, more likely,

by forcing air through a molecular sieve system at high pressures, concentrating the CO_2 on the upstream side of the sieves.)

While the receiver antennas contain some high-technology semiconductor components, assembly of the rectifying dipoles into panels about two square meters in size would require only slightly skilled labor easily obtained in large quantities in the cities. For a 10 GW station, the receiver antenna would characteristically cover an ellipse about 9 kilometers by 12 kilometers in size, totaling 340 million square meters. Assembly of dipole panels with wire mesh groundplane panels beneath, everything supported by a lightweight metal trusswork from primary support piers made of ferroconcrete, could be accomplished with minimal site preparation by unskilled and very slightly skilled labor (with skilled foremen) recruited from the rural countryside. Assuming the semiconductor components themselves are manufactured by highly automated factories, a labor estimate of 2.5 hours per panel 2 m^2 in area does not seem unreasonable. Each SPS installation then requires 170,000 man-years of semi-skilled labor, about equally distributed between rural and urban (factory) workers. Assuming the 75 SPS installations were to be constructed over a 15-year program, the construction program would provide 850,000 jobs across the country.

Each synthesis plant would require (initially) some 1.5 to 2 million 2-gallon containers (or their equivalent). These can be manufactured, in most places, from glass or ceramics, or could be brought in from petrochemical plants elsewhere if plastic jugs were used for greater energy efficiency. If glass or ceramic containers are chosen, 40,000 glassblowers or potters would be needed to equip the new synthesis plants with an initial supply of jugs. Assuming 3 to 10% breakage annually, 15,000 to 60,000 potters or glassblowers would be needed to sustain the fully implemented system.

Operation of the network of SPS receiver antennas and methanol synthesis plants would require up to 75,000 semi-skilled and skilled workers across India. Delivery of the methanol from the synthesis plants to the villages (if it were done entirely by bicycle, handcart, oxcart, etc.) would require as many as 10 million rural workers; the construction of regional pipeline networks to distribute methanol through ceramic or plastic pipes

would be more likely reducing the average distance of manual transportation (and the manpower required) by an order of magnitude or more.

Freeing up the cow dung presently used for cooking would increase the available fertilizers for agriculture, reducing foreign exchange imbalances due to fertilizer imports and improving the friability of the soil which increases its resistance to erosion. The methanol substitutes for more than 1,100 million tons of firewood (or other vegetable matter) each year (assuming population at the level projected for the year 2000) equivalent to the total biomass production of 20% of India's land area under natural growth conditions. This indicates the massive scale of ecological disruption posed by India's present (and projected) dependence on firewood and dung.

Additional impacts more difficult to estimate at the present time include the labor force needed to build the synthesis plants, the labor force needed if regional pipelines are to be built, and the effects of integrating the methanol distribution system with the postal system and delivery of other goods.

For India, the use of night illumination satellites is likely to be restricted to emergencies only, in particular, for rescue operations following floods or earthquakes. Such a system would need to be designed somewhat differently from one intended to provide urban lighting on a routine basis, in particular, with respect to the ability to rapidly change the beam's position over a wide region.

2.2.4 Brazil

2.2.4.1 Geography

Brazil occupies 8,512,000 square kilometers (3,286,500 square miles), nearly half the total area of South America, extending from 5.5° to 34° S in latitude which spans tropical, subtropical, and temperate climatic zones. A large portion of the interior is taken up by the forests of the Amazon River basin, much of which is still very poorly mapped. (In just the last three years, a previously unknown major tributary of the Amazon was discovered in a Sideward-Looking-Airborne-Radar survey of the basin.) A lengthy

coastline on the Atlantic Ocean provides Brazil with an extensive continental shelf for economic development as well, especially since widespread acceptance of a 200-mile limit for the "economic zone" of ocean space.

2.2.4.2 Population

The population of Brazil in 1973 was approximately 101.4 million people, not including the Indian population of the Amazon jungles for which very poor census data can be obtained. The average population density was thus 9.8 people per square kilometer (31 per square mile). The rural population in 1970 was only 44% of the total, with most of the urban population concentrated along the Atlantic Coast. The government is actively trying to develop the interior by building entire new cities from scratch. Urban planning for these new cities, however, has suffered from a legal system which grants very liberal rights to squatters, with very limited public right of eminent domain. These legal conditions have also contributed to the extensive slums surrounding the major cities.

2.2.4.3 Economic Conditions

The Brazilian Gross Domestic Product in 1973 amounted to about $77.9 billion (U.S.) or $750 per capita. The economy is highly diversified and fairly advanced in development. Services contribute more to GDP than agriculture and industry (excluding mining and petroleum) combined. About 21 to 23% of GDP has been reinvested annually, resulting in vigorous economic growth. The trade balance has generally been negative, due in part to the necessity to import petroleum and manufactured goods. The national economic development plans have emphasized the development of domestic industries to replace foreign imports of manufactured good whenever possible. The largest single export product (unground coffee) accounts for about 20% of total exports, while petroleum is the largest single import, accounting for slightly more than 20% of all imports.

Government policy has been, generally, to encourage private enterprise, with government's role primarily that of encouraging new industries. Education accounts for only about 8% of government expenditures, much lower than for most other countries in South America, where public education runs as high as 24% of government expenditure.

2.2.4.4 Societal Factors

Virtually the entire population speaks a single language, Portuguese, and 95% of the population is nominally Roman Catholic. Racially, however, Brazil is less homogeneous, with 60% Caucasian, 26% Mestizo (mixed European and Indian), 11% Black and 3% other as of 1950. Illiteracy is still a significant problem. The disparity between the wealthy elite in the cities and the slumdwellers in the same cities is a source of political unrest, and some urban guerrilla activities have presented acute difficulties for both government and industry, especially in cases of kidnapping for political purposes.

2.2.4.5 Potential Markets for Space Industrialization

The Brazilian government's current five-year plan (January 1975 to December 1979) aims at vigorous development of industry, agriculture, science and technology, human resources, and integration into the world economy, with more uniform distribution of industry and population across the country and careful attention to preservation of the environment. Potential areas of space industrialization relevant to Brazil in the next few decades include communications, weather, sensor polling, Earth resources, ocean resources, and navigation satellites; solar power and night illumination satellites; orbital materials processing; and space transportation facilities and (perhaps) launch vehicles.

2.2.4.6 Communications and Sensor Polling Satellites

Brazil's vast land area combined with a reasonable level of personal income (growing at better than 2% per year) provide attractive markets for communications satellites and sensor polling satellites of various types. Conventional telephone and television circuits already are in use by satellite; personal communications and direct television broadcast can be expected to make modest penetration of the Brazilian market during the late 1980's and 1990's, although the fraction of the population reached will be significantly smaller than for the United States. Development of a National Information Service could be subsidized by the government to stimulate the development of indigenous technological and scientific capabilities, in industry, government, and academia.

The focus in the development of the transportation infrastructure will be the use of natural waterways for surface transportation and the expansion of civil aviation. For river transportation, knowledge of flow rates and flood heights could improve reliability of the transportation system, and this data could be most readily gathered by remote sensors polled by satellite.

2.2.4.7 Weather Satellites

Agriculture, air transport, and industry can all benefit from comprehensive and up-to-date weather information which is presently unavailable over such a vast country. The government of Brazil already recognizes the importance of weather satellites to the future development of the country.

2.2.4.8 Navigation Satellites

As the interior of the country is developed, civil aviation, river shipping, and offshore oceanic shipping will all require far better navigation facilities than are presently available. These satellites (after the mid-1980's) can also provide sufficiently accurate position information for civil engineering survey work in the interior.

2.2.4.9 Earth and Ocean Resources Satellites

Brazil's mineral resources are as yet its least developed assets, primarily because of the enormity of the territory to be prospected. Protection of the environment and rational development of new agricultural areas along the rivers will depend heavily on satellite surveys. Rational exploitation of the Amazon forests likewise needs large areas surveyed rapidly and efficiently. Development of offshore resources (fisheries, possibly petroleum) cannot help but benefit from satellite surveys. Planning of highway construction and location of new cities, airports, and harbors will be much more difficult without satellites. The Brazilian government is already very much aware of these benefits of space technology.

2.2.4.10 Energy from Space

As yet, Brazil appears to have insufficient petroleum deposits to be self-sufficient for energy. Vigorous research programs are underway to

develop unconventional energy sources including ocean thermal electric conversion, fermentation of methanol from biomass including commercially raised crops such as cassava, and various other solar energy technologies. Nonetheless, during the next two decades, the government expects to install about 80 Gigawatts of nuclear power generating capacity for electrical energy demands of the major cities and industrial areas. If solar power satellites prove to be competitive in price with nuclear power, 4 to 10 SPS's could be deployed during the next two or three decades to fulfill the Brazilian demand for electricity. Night illumination satellites may find a reasonable market in frost protection for the coffee plantations, in accelerated construction of new cities to minimize problems with squatters, and in urban street illumination.

2.2.4.11 Materials Processing in Orbit

As we have seen earlier in this report, just which products manufactured in orbit in the new environment of space will prove to be economically successful remains to be seen. Present uncertainties are too large, especially in view of rapid technological progress in competing terrestrial alternatives. It is likely, however, that some applications will be found during the Shuttle/Spacelab program and in Shuttle Getaway Specials during the early 1980's.

Brazil's current five-year plan sets as a basic line for technological and scientific policy the transfer and adaptation of technology already available in developed countries in a number of sectors on a selective and rational basis which does not prejudice the development of domestic technology including that in complex areas. Special priority is placed on the development of new technologies, including space, nuclear energy, and non-conventional energy sources, and on the technological development of high-technology basic industrial sectors, including electronics, metallurgy, aeronautical equipment, capital goods, chemical and petrochemical industries.

The development of a Brazilian capability in materials processing in space is entirely consistent with these national policies and priorities, so that Brazilian participation in Shuttle programs should be vigorously encouraged by NASA.

2.2.4.12 Transportation Facilities

Brazil's equatorial position makes it possible to consider international launch and recovery facilities in Brazil. The mouth of the Amazon is directly on the equator, with excellent access to ocean transportation and existing cities and harbors on both banks. This area, however, does not offer highland sites, which may be a slight disadvantage compared to alternatives available in Indonesia, for example, or in western Brazil, where the Amazon River would still provide reasonable access, since it is navigable into Peru. Tourism and foreign trade generated by such a spaceport would contribute positively to Brazil's balance of payments, while the availability of new, high technology expertise and capability would have a beneficial effect on the "brain drain" while indirectly assisting in the upgrading of higher educational facilities in the sciences and in engineering.

The domestic aeronautics industry could expand its capabilities within a decade or less to become an aerospace industry, providing satellites, space hardware components, and perhaps even launch vehicles. This development is not inherently contingent on the development of an international launch facility in Brazil, but it would certainly be encouraged and accelerated by the presence of such a facility.

2.2.5 Environmental Issues of Space Industrialization

Like any other human undertaking, Space Industrialization will have numerous effects on the environment--some good, some bad. The purpose of examining possible effects before undertaking specific projects or programs is to improve the design of the system in order to maximize its beneficial effects and to minimize its adverse effects. Space Industrialization is too large and diverse a field and too many of its components are as yet in a very early stage of preliminary design to permit a single comprehensive environmental impact assessment at this time. Our aim in the present discussion is to outline a comprehensive framework in which issues requiring detailed study during the design process can be raised with reasonable assurance that major issues will not be overlooked inadvertently.

In order to be sure that we have not overlooked something obvious, each system must be examined in each locale in which it operates with respect to biological effects, physical effects, chemical effects, physico-chemical (coupled) effects, and electromagnetic effects. (Electromagnetic effects are a subset of physical effects; they are singled out here, however, because the electromagnetic frequency spectrum is a limited resource which requires attention to allocation between different types of potential uses with protection from interference by other uses.)

Space systems typically do not operate in only one small spatial vicinity. Most systems considered involve a ground site of some type, passage of physical objects or of energy through the Earth's atmosphere, and a specific facility in space. Depending on the position of the facility in space, the passage of artifacts or of energy through low-Earth orbital space, geosynchronous orbital space, the magnetosphere, the magnetopause, cislunar space, lunar orbital space, or solar orbital space may be involved. In some cases, planetary sites must also be considered (lunar surface, asteroid surface and interior, Martian surface,etc.)

In addition, for space systems which will compete with existing or anticipated terrestrial alternatives, it is necessary to consider the environmental effects of substituting a new space system for the alternative terrestrial system. (What, for example, would be the environmental benefits or liabilities of substituting asteroidal mining of nickel for terrestrial or ocean floor mining of nickel?)

Finally, a number of miscellaneous issues which do not clearly fall in any of the above categories must be considered. What, for example, will be the visual/esthetic impact of several dozen large Solar Power Satellites hanging in the night sky fully visible to the naked eye on Earth?

In the following paragraphs, we present a wide-ranging (but not yet comprehensive) set of environmental issues arising from several different space systems. Since space transportation is essential to all space industrialization activities, it is analyzed first. Some of the issues raised in connection with Solar Power Satellites have not, to the best of our knowledge, been raised elsewhere. Many of these issues may turn out to be fairly trivial; it is essential, however, that all of them be addressed responsibly if space industrialization is to avoid the anti-technological backlash the nuclear power industry has experienced because of premature dismissal of environmental and safety issues.

An example of iterative design based on preliminary environmental considerations has already been provided by the Solar Power Satellite. The frequency used for the microwave beam was selected, first, on the basis of the present allocation of the frequency spectrum by the International Telecommunications Union, and, second, on the basis of the absorption spectrum of the troposphere in the microwave band. Once this had been done, some preliminary calculations were made of the absorption of microwaves by the ionosphere. These calculations suggested that non-linear effects in the D- and F-layers would become significant for power densities in the beam exceeding 23 milliwatts per square centimeter. From this limit on power density, the size of the receiving antenna (for a given total power capacity for each receiving station) follows immediately, as does the size of the transmitting antenna aboard the satellite for any given satellite altitude.

Similar considerations of some of the issues raised here may result in limitations on receiver antenna placement, on SPS orbits (e.g., sun-synchronous with the beam moving through the atmosphere versus geosynchronous with the beam fixed in the atmosphere) and on antenna design to permit shared land uses.

We have not included any discussion of information services provided by space systems or of materials processing in low-Earth orbit because of the limited impact these would have in the next few decades beyond the impacts associated with transportation facilities and habitat and laboratory facilities in space.

2.2.5.1 Environmental Issues of Space Transportation Facilities

A. Biological issues

Biological effects of space transportation systems would be confined principally to the local site of the launch and recovery facilities. Construction of new complexes is inevitably disruptive to the local fauna and flora. The traffic of people, ground vehicles, aircraft and space vehicles will continue to disturb local wildlife or, at least, alter behavior patterns in the area due to noise, lighting at night, and powerlines and pipelines intruding on the area. The toxicity, carcinogenicity, and mutanogenicity of exhaust products, spills and leaks, or of dust, vapors, and liquids from explosions must be considered. Air quality, water quality, and land erosion from the activities of the launch site all create perils for local wildlife. Noise and vibration may disturb some species, particularly on a seasonal basis.

B. Physical issues

Noise and vibration over a widespread area may be associated with launch and landing operations. Natural dispersal mechanisms may limit the maximum rate of use of chemical rockets on the lunar surface if a permanent lunar atmosphere is to be avoided.

C. Coupled physical/chemical issues

The dispersal mechanisms for rocket exhausts (whether chemical, laser, or pulsed nuclear systems are being considered) must be examined and understood in the troposphere, stratosphere, and ionosphere. Photochemical processes are poorly understood at present; it is impossible at

present to state whether or not exhausts from launch vehicles would decrease ozone concentrations in the stratosphere or alter precipitation in the troposphere downwind from the launch site. Photochemical effects of laser beams used for laser launch do not appear to have been investigated.

Above the Earth's atmosphere, dispersal mechanisms for exhausts from chemical rockets, ion engines, plasma engines, mass drivers, laser rockets and nuclear rockets must be investigated in detail to determine the final destiny of these exhausts. Accumulation of such exhaust products in cislunar space (down to low-Earth-orbit) could have major climatic effects through alteration of solar insolation or of charged-particle deposition in high latitudes. Inadvertent destabilization of the Van Allen radiation belts by exhaust products could perturb the magnetosphere. Entry of mass driver ejecta into the upper atmosphere could alter the atmospheric albedo and photochemistry. Whether or not such effects become significant will depend on many factors such as use rate. The point here is that although probability of environmental damage appears low, it must be examined in each case.

D. Electromagnetic issues

Radio frequency interference and radio transmission blackouts may be associated with rocket exhausts and vehicle reentry through the ionosphere.

2.2.5.2 Environmental Issues of Solar Power Satellites

A. Biological issues

The long term biological effects of non-pulsed, non-ionizing microwave radiation on biological systems (including human beings) are as yet unknown. Short term effects have received some limited attention, with a great deal of controversy concerning safe levels of exposure for the general population. An extensive research program in this area is certainly urgent, and will have important implications for compatible land uses of rectenna farms.

B. Physical effects

Due to conversion losses, some thermal power will be released into the immediate vicinity of the receiver antennas. The effect of this "thermal pollution" must be examined in terms of weather modification in the vicinity of the rectenna. Some absorption of the microwave beam throughout the atmosphere must be expected, and it is important to assess the effects this heating may have on atmospheric circulation. Should a convective plume be induced by the microwave beam, the result might be a permanent thunderhead directly over the rectenna, restricting rectenna siting to locations with very low humidity. Should such a convective plume push through the tropopause, the global balance of water vapor and carbon dioxide transport between the troposphere and the stratosphere would be altered significantly by just a few solar power satellites.

C. Coupled physical/chemical issues

Microwave (or laser) beam absorption in the stratosphere may change the temperature of the air column within the beam slightly. Small temperature changes, however, can produce disproportionately large changes in the complex non-linear system of photochemical and chemical processes determining trace species abundances in the upper atmosphere, including ozone. Microwave beams passing through the magnetosphere may alter the ion/electron balance, with indirect effects on energy deposition in the Earth's polar regions of the upper atmosphere. The magnetosphere may also be affected by exhaust products (gases, plasmas, or ions) from station-keeping systems for the solar power satellites.

D. Electromagnetic issues

Assuming microwave power transmission is used, frequency allocations, side lobes, and side bands from the transmitter antennas must be considered carefully. Scattering (re-radiation) from the receiver antenna array on the ground may be a problem as well in some areas. Frequency allocations must consider interference(constructive as well as destructive) between side lobes of different power satellites.

E. Comparative issues

A comprehensive review must be made of the comparative environmental issues of solar power satellites versus possible competing technologies such as conventional fission reactors, breeder reactors, fusion reactors, coal, petroleum, ocean thermal, and terrestrial solar. Data reviewed to the present seems to favor the SPS in terms of total relative impact with the exception of ocean thermal where the effects are also not presently understood.

F. Other issues

The visual impact of the deployment of multiple solar power satellites must be defined. While all SPS designs involve satellites of very large size, differences in configuration may result in major differences in their obtrusiveness to the naked eye. The effect several dozens of geosynchronous power satellites may have on bird migration (which has been shown to be based on celestial navigation for a number of species) can be tested on captive birds in planetarium simulations. The impact on ground-based astronomical observations must also be defined.

2.2.5.3 Environmental Issues of Habitats in Space

A. Biological issues

For habitats and experimental facilities located on the surface of Mars, the surface of the larger moons of the outer planets, and in regions of the lunar surface where volatiles may be concentrated by natural mechanisms (such as craters in polar regions), contamination of the planet by terrestrial microorganisms must be avoided until it has been established unequivocally that no indigenous lifeforms exist.

B. Physical issues

Any pressurized space structure will inevitably release gases and vapors through small leaks, through airlock cycling, and by station-keeping reaction engines. If the total rate of emission of these products were sufficiently large in cislunar space, solar insolation for Earth could be altered. Similarly, should the rate of emissions from habitats on the lunar surface (combined with chemical rocket exhausts and outgassing of

disturbed surface layers during mining operations) exceed some threshold, a sensible atmosphere may be created artificially, with a long lifetime.

C. Coupled physical/chemical issues

Dispersal mechanisms and interactions between emissions from habitats in cislunar space with the ambient magnetospheric plasmas must be examined to assure that the density and composition of the radiation belts is not altered in a manner which would have major repercussions on solar insolation and the deposition of charged particles in the polar regions.

2.5.5.4 Environmental Issues of Nonterrestrial Mining

Mining the Moon or the asteroids for the construction of solar power satellites would raise environmental issues similar to those already mentioned for habitats in space. Mining asteroids towed into high orbits around Earth would raise a few additional issues if raw and finished materials produced from these sources were subsequently imported to Earth.

A. Physical issues

Would ablative losses from payloads to be delivered to the ground significantly affect distributions of small particulates in the upper atmosphere with long-term climatic effects?

B. Comparative issues

For each material under consideration for import from space, a careful assessment must be made of the environmental effects and issues posed by the terrestrial sources of that material. Copper mining, for example, presently produces significant quantities of biotoxic leachates from extraction processing and from mine tailings. Replacement of these mines by copper imported from captured asteroids may be desirable in comparison.

3. DOMESTIC IMPACTS AND ISSUES

Space Industrialization (SI) will have impact and meaning in many areas of human endeavor in the United States as well as the world. These impacts may be more subtle than profound, given the level of economic and technical development already enjoyed by the U.S. Nonetheless, these impacts will be important and, indeed, can provide the stimuli necessary to assure U.S. economic growth through the last decade of this century and into the next. The realization of these impacts in a positive fashion will depend completely on establishment of government roles supportive to greatly enhanced private sector involvement in space.

This section will first address the magnitude of the anticipated impacts given certain assumptions related to settling the latter issues (government/industry roles) in a fashion favorable to SI growth. Then the perceptions, recommendations and views of industry will be presented based on surveys conducted during the study. Some impacts that may be postulated from future scenarios, market potentials and programs (discussed in Volume 2) but not examined in detail are energy availability, increases in scientific knowledge, new or reformed social institutions and options for unforeseen futures. The impacts to be discussed here will be specifically economics (taxes, GNP), jobs and balance of trade.

3.1 EMPLOYMENT AND ECONOMY IMPACTS

Positive contributions to the United States economy accrue from several considerations related to SI. The providing of services today results in capital expenditures for equipment, salaries, tax generation, payment for launch services and sales to other nations. The exact level of these benefits is difficult to assess since specific expenditures in the United States are generally buried or subject to various constraints on dissemination. Published data in the Congressional Record (FY 77 and FY 78 Appropriations Hearings for NASA) and various annual reports lead to the following general breakdown on current expenditures specifically related to space industrialization.

	IN 10^6 $/YEAR
Foreign Satellite Purchases	150-250
Procurement and Operation of Remote Sensing Systems	100-150
COMSAT Operations	150-200
Other Operations	50-150
Domestic Satellite Purchases	50-100
Re-Imbursable Launch	100-150
	600-1,000

Not included are expenditures related to the U.S.S.R., its aligned nations or the Peoples Republic of China. Also, expenditures within foreign governments or agencies not related to U.S. launch activity are not included. Neither are ground station purchase, installation or operations included. Purchases alone in the U.S. are estimated at 50-100 million dollars annually.

From the known expenditures and an overview of the unknowns, it is possible to surmise that total world transactions are currently well in excess of one billion dollars per year. The discussions of Section 2 indicate that this figure will grow steadily, at least for several years. INTELSAT alone is projected to grow in numbers of channels by 17 to 20 times by 1993. The U.S. total use of GEO for Information Services using todays systems and technologies will be limited to about three times current usage, however. Minor advances in the technologies related to multiple frequency use, interference suppression, etc. will lead to greater capacity both in the U.S. and around the world. Since worldwide data needs are projected to grow by more than two orders of magnitude (>100) by 2000, it seems likely that annual revenues and expenditures will exceed 10 billion dollars before then.

This extrapolation is centered around growth trends from a variety of sources. The economic impacts examined in this study were based on an alternate approach to simple trend extrapolation. From the scenario, market and program work reported in Volume 2, it was surmised that significant opportunities existed in the near future in the public

and private sector. If advantage is taken of these opportunities, a much greater benefit to the U.S. and world can be realized than would be predicted by simple trend forecasting. Thus the analyses whose results are presented here were structured to show what could happen, and hopefully help precipitate the required actions. As mentioned in the discussion on Future Scenarios (Volume 2), an implicit assumption in all analyses was that opportunities would be capitalized on, the extent of which varied between scenarios. This is reflected in the six programs developed and presented in Volume 2 and more specifically in the two programs analyzed in detail. The following benefit calculations are based on those analyses.

3.1.1 Assumptions

Certain assumptions concerning the nature of the industries involved in stimulating and handling the revenue flows were necessary. Composite indices were developed and applied across the board without specific variation between industry types, products vs. services, etc. Given the composite nature of the expenditures and revenues on a whole program basis and our uncertainties, even detailed indices would yield aggregate approximations. Thus a more detailed industry-by-industry assessment is not warranted until more specific analyses are performed on the projected revenues and costs.

The specific indices used were:

$$\frac{\text{BEFORE TAX PROFIT}}{\text{GROSS REVENUE}} = 0.20$$

TAX BRACKET = 0.50

LABOR INTENSITY (OPERATIONS AND MAINTENANCE) = 0.40

COMPOSITE MEAN SALARY = $17,000 ANNUAL

These figures are typical of various service industries today subject to government regulation. Although profit margin for COMSAT was somewhat higher in the past, the trend has been to force it downward. As discussed in Section 6 of this Volume, after tax profits have varied from six to fifteen percent typically.

Current corporate taxes are 49 percent. For simplicity, a straight 50 percent was used.

Operations and maintenance for service industries of the type postulated as markets have often exceeded 50 percent of net revenue. During periods of growth and investment the number tends to be lower than after achievement of maturity. The recent COMSAT experience of 41 percent was taken as typical.

The Composite Mean Salary used is slightly higher than the National Mean of 1977 (about $15,500 annual) due to the assumption that people with above average skills would be a significant part of the labor force in Services.

Calculations were performed for two points in time. First, 1985 was selected as a representative near term year where almost all new revenue in SI would be investments. This was assumed to be almost purely public funding (government sponsored development programs). The latter year chosen was 2010, the end of the time period being examined (1980-2010). The revenue in 2010 is projected to result almost entirely (>95%) from sales of Services, Products and Energy (People in Space revenues are insignificant compared to the others).

3.1.2 Results

Jobs and taxes generated were estimated for three programs; the Energy Breakthrough (No SPS), the Baseline (with SPS), and the Upside (all initiatives). Although the Upside is considered the least likely of the three (requiring heavy investment in the early eighties), it was desirable to assess the potential impact of such a strong, aggressive set of initiatives. The results were as follows:
(For comparison with the companion Rockwell International report on SI, the NO SPS corresponds to Plan C, BASELINE to Plan A. An UPSIDE type program was not addressed by RI.)

	NEW JOBS*		
	NO SPS	BASELINE	UPSIDE
1985	15,000	100,000	120,000
2010	1,000,000	1,900,000	3,800,000

* DIRECT ONLY. U.S. MARKETS ONLY

	TAXES GENERATED*		
	NO SPS	BASELINE	UPSIDE
1985	$ 100M	$ 800M	$ 1000M
2010	$10,000M	$ 20,000M	$40,000M

* DIRECT ONLY. U.S. MARKETS ONLY

The estimate of jobs for 1985 is probably low by a factor of two since most funding would be to the aerospace industries. The Aerospace Industries Association (AIA) has estimated that about 30 direct jobs are created for each one million dollars of appropriation. Direct plus indirect jobs are estimated to total about 100 jobs per one million dollars. Thus the job projection for 1985 is conservative since the computation was the same as for 2010. The true impact on new jobs is some two to four times the numbers shown here depending on specific assumptions and economic theory applied.

Exactly how many of the new jobs are displacements of old jobs or creation of new ones is difficult to speculate. Very little displacement is anticipated since most of the new capabilities afforded by SI are complementary to existing systems. It is highly unlikely that the personal pocket telephone will replace the corporate system as long as the economics are comparable. Also, in most business complexes interference and shielding could present considerable difficulty and an added expense to accommodate pocket telephones.

Residence telephone service would be the most likely to be effected with some decrease in numbers served and associated jobs. This would not exceed 50% of the potential portable telephone users (assuming an average of two per household) or 10% to 20% of the services, products and energy revenue (depending on SI program). All other services (with the possible exception of Electronic Mail, which needs better definition) are additive (new).

Likewise, energy initiatives will add to our present domestic supply. Some products will displace those utilized today, some will be new and unique.

In the aggregate, the best guess is that 75% or more of the postulated SI initatives revenues will be job creating in the nineties and beyond. Thus for a workforce of 100,000,000 in 2010 some three to twelve percent could be employed in new jobs created by space industrialization.

The tax revenue calculations take into account corporate taxes based on previous assumptions plus personal income taxes of direct employees. A national composite rate of 0.26 for federal and state income tax was applied to personal income.

3.2 SAMPLE INDUSTRY COMMENTS AND RECOMMENDATIONS

Industry representatives involved in private enterprise in the three major categories (Information Services, Energy and Products) were contacted. The purpose was to obtain information on how government and industry could cooperate and complement in order to make space industrialization grow.

The contacts consisted of:

Information Services - two contacts in the satellite communications business.

Energy - two contacts in power R & D
- two contacts in the investment community

Products - nine contacts in non-aerospace manufacturing

Before evaluating the concepts and potential for SI and expressing their opinions each of these stressed the need for anonymity for themselves and their company. Only in that fashion could complete candor be obtained.

3.2.1 Perceptions

Each individual was given both written and personal briefings on what SI consists of and what this study was about. Discussions were typically tailored to the specific industry of interest.

The essence of industries perceptions on the status of SI today is summarized in the simplistic qualitative chart of Figure 3-1. This can also be considered something of a prediction on what will happen given risk reduction initiatives. There is no general lack of faith in the

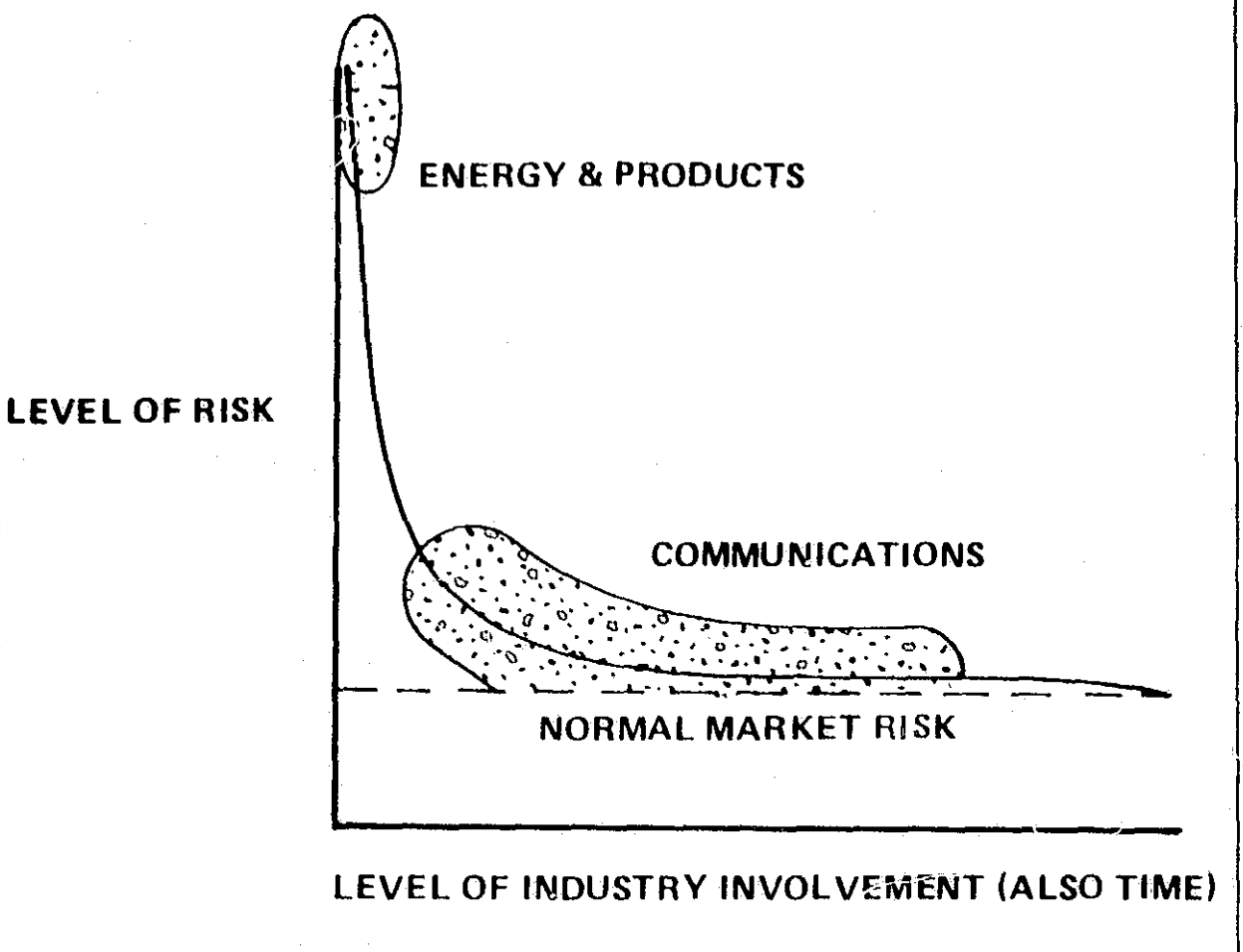


Figure 3-1. Schematic Summary of Perceptions by Industry Contacts Regarding the Present Status and Probable Future of Levels of Risk in Space Industrialization.

future of space industrialization in any area, only a perception that the economic risks of involvement are very high relative to normal market risks except in the more mature communications industries. As the risks come down with new knowledge, demonstration programs, government initiatives, etc. (marked by the passage of a block of time) it is anticipated by all contacted that the level of industry involvement will increase substantially.

At present, however, a corporate leader/manager cannot justify any investment in products (at the basic research stage and having much too high transport costs) or energy (overwhelming techno-economic risk). The more expensive communications systems (such as the Orbital Antenna Farm of Morgan and Edelson, COMSAT) are being looked at rather seriously, although the total capital and payback times on larger systems look doubtful (see Section 6, this Volume). One simple message is certain. As techno-economic risks come down, U.S. industry will steadily increase its allocation of resources to SI if a reasonable payback can be obtained. "Reasonable payback" will vary broadly based on initial investment, near term vs. long term risk, guarantees, etc.

3.2.2 Industry Views on Roles and Responsibilities

The specifics of appropriate roles and responsibilities which could be adopted by industry and government vary broadly according to the industry and the individual. It is possible, however, at the rather gross segregation level presented in Figure 3-2 to assemble a set of consensus opinions. As might be anticipated the communications industry is sufficiently mature that the Product Development and Pilot Operations areas require consideration of specific proposals to obtain a particular opinion. The large geo platform concept was one initiative that generally fell in the joint venture category for example. A new version of an existing satellite system was considered to be an appropriate industry activity. Particular attention is drawn to the consensus or CEP blocks.

The information presented here is considered as a stage setting providing general guidelines for development of specific arrangements on a case by case basis. Early general agreement to these guidelines by government would encourage enhanced industry involvement in Space Industrialization.

INDUSTRY IDEAS ON ROLES & RESPONSIBILITIES

C – COMMUNICATIONS
E – ENERGY
P – PRODUCTS

	GOVERNMENT ACTIVITY	INDUSTRY ACTIVITY	JOINT VENTURE	GOVERNMENT REGULATION
BASIC RESEARCH	C E P			
APPLIED RESEARCH	E P		C	
PRODUCT DEVELOPMENT	E	C*	C* P	
PILOT OPERATIONS	E	C*	C* P	
PRODUCTION OPERATIONS		C E P		C E
TRANSPORT DEVELOPMENT	C E P			
TRANSPORT OPERATIONS		C E P		C E P

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*DEPENDS ON SPECIFICS

Figure 3-2. Industry Views on Roles and Responsibilities

3.2.3 Specific Feedback and Recommendations

The following subsections provide the specific comments, concerns and recommendations received from the industrial contacts. Additional information was gathered from less formal contacts at technical and management conferences. A particularly useful reference in this area is Dula, "Legal and Economic Prerequisites to Space Industrialization", Proceedings of the Nineteenth Colloquium on the Law of Outer Space Activities by Private Enterprise - Introductory Report, (1977), 257.

3.2.3.1 Industry Feedback - Communications

CONCERNS

- The scope of planned and projected geosynchronous satellite activity is not generally recognized.
- Possibility of beam interference by 1981 is real and significant.
- Intelsat alone is projected to grow by a factor of 17 to 20 times (channels) by 1993; over 100 times by year 2000.
- Certain communication satellite technologies are lagging in the U.S. due to a lack of stimulation. Examples:
 - Large deployed solar arrays
 - Momentum wheels
- Crowding (frequencies and GEO orbit) will lead to communcations "rationing" in the 1980's unless:
 - Integrated platforms are developed.
 - Terrestrial technologies take over.
- Some organized coordination and stimulation is necessary if general technical leadership is to be regained by USA.

RECOMMENDATIONS

- Promote government agency (FCC, etc.) acts fostering space competition to ground capabilities.
- Promote cooperative international planning on the use of GEO-SYNC in the eighties.
- Do an orderly assessment of the status of U.S. technology.

- Analyze pieces currently being used.

- Project future most probable origins of hardware.

- Stimulate selected developments.

- Government should serve in R&D capacity only, with industry fulfilling the requirements of pilot and operational program.

3.2.3.2 Industry Feedback - Energy

ATTRACTED TO SPS CONCEPT BY

- SPS is a potentially open ended kind of solution but with a potential for relative near term (1995+) implementation.

- The potential for low installed power cost after the R&D is complete ($2000/$KW_E$ is general threshold) looks attractive.

- It has the potentially most acceptable environmental impact of baseload alternatives if the microwave issues are settled.

- It neatly separates generation (SPS) and distribution (rectenna + wiring, etc.) issues and systems.

- It avoids future issues concerning hydrocarbon resource (coal) allocations such as national defense, fertilizers, etc.

BARRIERS

- Public perception of microwave radiation "hazards".

- Supporters of terrestrial alternatives, particularly fusion.

- The level of cost risk is much too high today.

- The Carter Administration will tend to ignore and downplay such bold new initiatives as detracting from the need to conserve.

RECOMMENDATIONS

- Stop treating the SPS like a space program and start treating it like a power program. Sell generation to the power companies and electricity to the consumer. Don't make a big deal out of the fact that its coming from space. That is incidental.

- Develop a plan designed to specifically demonstrate acceptable risk level for investors.

- Develop a businesslike approach and get the message into Fortune, Forbes, etc.

- Develop a working relationship with every state and every power company in the U.S.
- Address the long term military, economic and industrial impacts of depleting hydrocarbon resources.
- Learn to understand and assess job impacts.
- Put priority on biological and environmental research but don't get bogged down.
- Go for strong information system synergy.

Perhaps the two most significant comments are the first and last. The first is a direct admonition to sell the benefits, not the program. The power companies never sold electricity by showing smokestacks, generators, dams and power lines. SPS should be presented to power companies on the basis of generation and distribution benefits to them and sold to the public as an investment in clean, cheap electrical power.

The last point reflects the observation by these reviewers that the demands for power in space in the eighties and nineties will provide a strong forcing function for an SPS prototype size program. A technology and development program should thus be possible which maximizes benefit to both SPS and future information systems.

3.2.3.4 Industry Feedback - Products

A substantial amount of work on previous studies related to products has been done. Of particular interest are those by GE, TRW and MDAC. In this study a different approach was desired. Specifically, product manufacturers were sought who were non-aerospace and had little or no previous contact with space processing or manufacturing concepts. After providing them information on SI in general and space processing in particular, extensive follow-up discussions were held.

The data gathered here presents one of the best overviews on how main-stream U.S. industry thinks, works and makes decisions. Thus a more comprehensive write-up is included in the products area followed by a summary of comments and recommendations.

These comments came from managers in the following companies:

1. Arthur D. Little, Inc.
2. Ball Brothers Research Corp.
3. Shell Oil Company
4. Talley Industries, Inc.
5. U.S. Polymeric Corp.
6. Arvin Industries, Inc.
7. Olin Chemicals Corp.
8. Union Carbide Corp.

The ninth contact is currently an individual investor and a past company president.

In almost all cases, the feedback revealed that the domestic industrial world is not aware of the real import of the NASA Space Shuttle or of NASA activities in Space Industrialization. They view extraterrestrial materials, lunar mining, space habitation, and anything much beyond earth-orbital operations as being "far-out Buck Rogers stuff". Such visionary planning turns them off to the near-term realities of Space Industrialization when the total concept is not properly presented.

Nearly every contact stressed the fact that the work to date is too shallow to provide a data base for industrial decisions. Very few proposed products or services would survive the rigors of a typical corporate planning review; several contacts provided detailed descriptions of their own firm's reiterative review schemes. Specific comments included: (a) the proposed products are too poorly defined at this time, and therefore (b) the markets are too indefinite and cannot be rigorously evaluated; (c) some terrestrial alternatives appear to be cheaper in view of perceived space costs (d) the experimental data is too soft for industrial use, meaning that it is too theoretical and too fundamental to reveal solid products and permit applied researchers and engineers to get firm grips on production processes and costs; (e) many things that are taken for

granted by space advocates and those involved in Space Industrialization at this time are viewed at highly theoretical and unsubstantiated; (f) the risks involved are very large relative to the capital outlay required, even to determine product or service feasibility; (g) the return-on-investment times are far too long for consideration by executives who must report to Boards of Directors who are in turn responsible to stockholders, as most ROI times range from 5 to 10 years at the very most, the longer times being acceptable only to firms with very large gross sales; (h) space transportation costs are viewed as being too high, usually by a factor of ten and even as much as a factor of 100 in some cases.

In spite of this somewhat negative viewpoint, it was highly encouraging that all the contacts admitted that the prospects for pace Industrialization looked "interesting". They all wanted to see more data. Nearly every one of them said that they believed their companies would get involved in Space Industrialization if their competitors did. It should be pointed out that at least one of these firms is already involved in a product or service which could directly benefit from one of the Space Industrialization services studied by SAI: large scale data transfer and electronic teleconferencing. Therefore, some of the negative comments should be viewed as "protective". Macy's does not tell Gimbel's. It is to be expected that domestic industry would like to appear to be very hard-nosed and conservative with respect to space industrialization while at the same time taking very hard and continual looks at it.

All contacts felt that an appropriate risk-reducing or risk-sharing policy on the part of the federal government would greatly spur interest and involvement from practically all segments of industry. This is to be expected, too, since it is to any firm's advantage if the government will underwrite, subsidize, or otherwise bear some of the R&D costs that would otherwise have to be amortized over the production run. There is also historic precedence in our own history for this sort of government-industry co-operation in the areas of high-risk and large capital outlay requirements.

Most contacts said they would like to see more NASA-sponsored R&D that would be relevant to products and more NASA R&D that fell into the



realm of applied research on products and services. Most of them are aware of the fact that much work remains to be done in the basic theoretical side of space processing before applications can be identified, but they felt that far too much stress was being placed on pure or theoretical research in this area with little understanding of their own earth-bound problems that could possibly be solved through applications of space processing.

Finally, all individuals stated they would like to see better communications between NASA and themselves in their own language with an awareness of their own problems evident. They were not aware of current NASA activities in this area beyond the technology utilization efforts which, according to most, were somewhat exotic and unrelated to their needs.

The industrial contacts stressed the fact that it would be up to NASA, they felt, to establish these channels of communication because it is NASA that has a service and a product to sell to them. They have trouble understanding the NASA approach and language, and they are reluctant to take the time and expend the effort to learn the language of an organization whom they view as a supplier. Most of them are very market- and sales-oriented, and therefore extremely sophisticated in these areas; as a result, most of them view most of NASA efforts as being very amateurish.

Although some of the advanced planning publicized by NASA and being carried out by some academic groups that have become advocates may be useful in creating enthusiasm among the intelligensia and young people, domestic industry views this as too visionary and believes that it may actually be hurting their chances to sell Directors and stockholders on the advanced work requirements they might like to do in Space Industrialization. This is because there is considerable confusion today between Space Industrialization--the cold, hard nuts-and-bolts of profitable space operations -- and space habitation, which appears to be Elysian and Utopian . . . and therefore unworthy of consideration for risk of capital.

Recommendations arising from a study of these feedbacks from industrial managers, financial planners, and production engineers include the following:

1. Establish better communications with domestic industry through an intermediary who can filter, translate, integrate, and smooth the flow of data in both directions without loss of confidentiality. Middle-men and interface groups are well-known and widely-respected within domestic industry; most mergers and acquisitions are carried out by interface groups, to say nothing of hiring executive personnel.

2. Establish a Space Industrialization newsletter that comes out regularly, is intended to be read by managers, executives, financial planners, and operating people in domestic industry. It should be written in language understandable to these people and contain information that may be useful to them.

3. Establish a means of sharing risks and costs of initial participation in Space Industrialization, particularly over the next ten year critical period of start-up in the field.

4. Reduce space transportation costs. One contact pointed out that he could never justify making things in orbit with a transportation cost of even $100 per pound when his current product that is satisfactory in the existing market costs only $1 per pound ready-to-ship.

5. Begin efforts to make space processing research relevant to existing product and process problems in industry; this can probably be done only by people who have an intimate inside knowledge of a particular industry, since many production, product, process, and service problems are known only to those in that industry or that one particular company.

PERCEPTIONS

- Work to date is too shallow to provide data base for industry decision on interest.
 - Products poorly defined.
 - Markets too indefinite.
 - Terrestrial alternatives appear cheaper.
 - Experimental data too soft.
 - Theoretical basis unsubstantiated.
- Risks are too large relative to capital outlay required.

- ROI too far down stream.
- Transportation cost too high by factor of 100 or more in most cases.

BUT

- The prospects are "interesting".
- Would like to see more data.
- Will get more involved if the competition does.
- Would like to see relevance in NASA sponsored R&D for their products.
- Want channels of communication established on a broad, up to date basis.
- An appropriate risk reducing or risk sharing policy will spur interest and involvement from practically all segments of industry.

RECOMMENDATIONS

- Establish better communications with domestic industry by means of:
 - Interface organization.
 - SI newsletter with background and current information.
 - Continual feedback from domestic industry.
- Establish means of sharing costs and risks of SI R&D.
- Reduce transportation costs.
- Make research relevant to potential products.

4. LEGAL CONSIDERATIONS

The legal considerations which must be recognized in any broad examination of Space Industrialization are, at first glimpse, staggering in their number and complexity. Entire symposia and extensive sessions during various astronautical conferences have been devoted to deliberations on interpretation of existing and proposed agreements, treaties, statutes, etc. In this study, there was no attempt to provide legal interpretations of laws and agreements. Instead, expert opinion was relied on to ascertain the answers to two simple questions: Are there any international laws or agreements which would preclude or severely limit evolution of any of the SI initiatives discussed in this study? Are there domestic laws (in the U.S.) with similar potential for limitation?

The experts consulted were:

Delbert D. Smith (through Rockwell International)
Katherine Drew Hallgarten
Arthur M. Dula

All are lawyers with a deep personal interest in space law. All provided their opinions informally to SAI. Dr. Smith had provided his formal assessment of the subject to Rockwell International as part of their SI study. That document is provided as part of the Appendices in Volume 4.

4.1 INTERNATIONAL LAW

In addition to the expert discussions, a number of papers and books on the subject of space law were given cursory review to obtain the "flavor" of internaional debate. The legal state in the international arena can be summarized as follows:

- Much interpretation, negotiation and rhetoric in progress.
- No seriously limiting treaties or international law in effect.
- Pressure in U.N. to adopt motions limiting SI activities will probably increase.
- Integrated technical, economic and legal planning necessary to avoid future problems.

The literature review supported the opinion that much discussion on international law and space is in progress but that no seriously limiting universal agreements have been made. However, a number of equatorial and/or developing nations have expressed their determination to play a larger role in controlling Space Industrialization by international agreement. This is exemplified by the current increase in the number of such countries represented on the U.N. Committee on the Peaceful Uses of Outer Space.

The last point presents that action needed to quiet an often expressed fear that some potentially desirable long range goals (such as use of lunar material) may be precluded or seriously hampered by improperly coordinated treaty agreements. In the nearer term similar dangers also exist. For example, the 1977 World Broadcasting Satellite Administrative Radio Conference (WARC) of the International Telecommunications Union (ITU) agreed to limit access to geosynchronous Earth orbit (GEO) for fixed-service and direct-broadcast satellites operating at 12GHz. In essence, fixed-service and direct-broadcast satellites cannot co-occupy segments of GEO when operating down-link at 12 GHz. This is not severely limiting at present since downlink for broadcast at 14GHz is perfectly acceptable. However, the "carving up" of GEO could lead to limitations on large, multiuse platforms and exclusion of certain potentially beneficial services. It will be necessary to form a strong working relationship between the government representatives to such conferences, cognizant industry representatives and long range planners to prevent continuing stepwise erosion of the promise of space. Continuous contingency planning and an occasional tough stand by the United States will undoubtedly be required.

4.2 DOMESTIC LAW AND POLICY

The consensus opinion obtained in the domestic arena can be summarized as follows:

- "These . . . considerations suggest that private sector participation in space operations is desirable. Nonetheless, a number of trends suggest that national . . . policy may be moving away from promotion of full-scale commercial involvement."
 (See Appendix by D. D. Smith)

- Anti-trust law and sec rules appear to limit "Distribution of Risk".
- Consideration of industries viewpoint is imperative in tailoring law and policy to promote SI.

Policies and rules (often based on interpretation of law) seem to have the highest potential for domestic impediment of space industry initiatives. Policies related to control of systems and data (such as Landsat and shuttle/spacelab for example) have received substantial attention and some trends as reflected by the quote here are apparent. Some laws and rules, imposed due to other national considerations, may inhibit the bringing together of sufficient capital and capability to address the more aggressive SI programs. The impact of such prior enactments will have to be addressed on a case by case basis as circumstances dictate unless general guidelines are established ahead of time. Because of the special factors surrounding potential SI investments, it is considered extremely important by our reviewers that industry viewpoints be factored into any proposed tailoring of laws and policy affecting SI.

4.3 SUMMARY

At present, Space Industrialization is not suffering substantially from either international or domestic legal constraints. The large scale initiatives discussed in this report for implementation in the 1980 - 2010 period could all be exercised today within the legal structure. However, all indications are that a series of initiatives to limit the U.S. and its industry are in existence or being originated. A net effect of these in the light of no established national policy in this arena will be to increase economic risk and foster impediment to industry involvement in SI. Without steps to assure industry in these matters, Space Industrialization may falter regardless of economic and technological enticements.

5. INSTITUTIONAL IMPLICATIONS

5.1 OVERVIEW

The growing perception that commitment to exploration and use of space may emerge as a primary determinant of national destinies, arises from several basic characteristics of astronautic activity and its potential impacts on future life and times. First, though the subject is not yet frequently discussed in much detail, it is widely acknowledged that space capability has become an established necessity as a cornerstone of modern national security posture, especially as regards information gathering and communications. Second, it is evident from the considerations and analyses of the present study that utilization of the energy and material resources to be found in space, and of the unique qualities of the space environment, can have potentially great impact on national economies, industry and education. Third, it is a matter of record that astronautic activity produces significant contributions both directly and catalytically to the advancement of a broad range of technologies and their diffusion throughout the society. And fourth, the new capabilities and resources opened up by space programs, if applied appropriately, can help strength national allies and alliances as well as the domestic health of the nation itself.

The approach to astronautic activity, then, will be a matter of the highest importance to both space-capable and "terrestrial" powers in the coming decades, and the effective use of space will require pervasive measures for policy unification and infrastructure organization, both nationally and internationally.

Recognition of this has begun to be apparent in the USSR which has within recent years unified its space programs under a new high-level office, Intercosmos, in Europe where the ESA organization is in place and functioning, and in "Japan Incorporated" where the national space program is coordinated under the Space Advisory Committee (SAC) reporting directly to the Prime Minister. A first attempt at space policy unification in the U.S. is reported to be in process within the present administration, aimed at more efficient coordination of intelligence, defense, civil/government and civil/private activities within a new policy framework.

In addition, major industrial infrastructure shifts have occurred in Europe, including the spreading formations of industrial consortia as noted previously, the nationalization of the British aerospace industry and the "rationalization" of Aerospatiale and Dassault in France. Further, formal discussions among government and industry representatives have been undertaken in Germany and Holland over possible consolidation of the West German aerospace industry, including the binational VFW-Fokker firm. The primary motivations toward such a consolidation are to enhance competitive posture vis-a-vis the nationalized British and rationalized French organizations, trim the industry's facilities, resources and capacity to be more efficiently in line with current workloads.

In this context it seems not unrealistic to project that similar restructuring may eventually be appropriate within U.S. government and industrial aerospace organizations. One such consolidation which occurred during the decade of the 1960's was the McDonnell-Douglas merger, a move which appears to have been quite successful. Within government, the suggestion has frequently been heard in recent years that NASA's effectiveness suffers from overcapacity as a result of budget decreases since the Apollo program, and that it may eventually be appropriate to alleviate this and resulting duplication of effort by closing down one or more centers.

Concurrently important together with the issues of space policy and organization is the general question of technology management. Effective development and use of technological resources is a key determinant of the future viability of any industrial or post-industrial society. This is particularly true for advanced nations or groups of nations which aspire to spacefaring. The U.S. has long led the work in the creation and application of new technologies but in the last decade this leadership has diminished.

The fraction of the U. S. gross national product devoted to research and development (R&D) has declined steadily for more than ten years, falling nearly one-fourth from its peak level of 3% in 1964. In 1977 after adjusting for inflation, the total funding is lower in real terms than ten years earlier. This is in sharp contrast to the significant increases found in many industrialized nations. For example, West Germany increased its expenditures for R&D by 40%, the U.S.S.R. by 42% and Japan by a striking 74%.[1]

1. Vanderslice, T. V., "U.S. Technological Balance of Trade is in Jeopardy", L.A. Times, Nov. 6, 1977, Part VIII, p.3

Technology administration is a complex subject covering a broad range of considerations - for example:

I. Technology Planning
 - A. Objectives and allocation of effort
 - B. Qualified human resources base
 - C. Public information and attitudes

II. Technology Acquisition
 - A. Internal (research, development and innovation)
 - B. External (technology import)

III. Technology Application
 - A. Internal
 1. Cross fertilization (often called "technology transfer")
 2. Diffusion (e.g., by capital investment)
 - B. External (technology export)

In the U.S., technology administration has barely begun to be perceived and articulated as a critical national function. Our technology management, particularly as it applies to our competitive edge with the rest of the world, is conducted by a large number of uncoordinated or loosely coordinated efforts. Various agencies of the Government, industry, the military and the intellectual community are all involved in many aspects of national technology management. This situation to date has been going on without either a clearly defined national technology policy or a clearly defined set of administrative responsibilities and mechanisms. As a consequence, each organization has almost independently set up its sphere of influence and its methods of functioning in line with very broad responsibility assignments. While this may have been acceptable in years past, we are in fierce competition both economically and militarily with other developed countries. It appears timely to get national technology policy better stated, responsibilities better identified, and implementation mechanisms and assessment of effectiveness upgraded. Unless this is done, the biases of each organization involved in national technology policy will dominate its actions with serious national consequences.

In other advanced nations such as in Europe and Japan the process is better organized, because a disciplined awareness has been cultivated among government officials, industrial marketeers and other interests, that they must necessarily act in concert. In these nations, one finds governments subsidizing commercial as well as military developments, offering loans and attractive credit arrangements, using political muscle to sell at the diplomatic level and managing both the withholding and export of technology in a coordinated manner and in accordance with defined national policies. In the U.S.S.R. the entire process is centralized under the State Committee on Science and Technology, one of the chief planning and coordinating agencies of the Soviet Government. This committee reports directly to the U.S.S.R. Council of Ministers and is equivalent in status to the defense and industrial ministries. Such centralization implies distinct potential advantages in dealing with a multiplicity of outside interests.

The decline of U.S. technological leadership is further reflected in an array of statistics from which illustrative examples can be drawn for several areas: Innovation: Between 1961 and 1972 the number of U.S. patents issued to foreign applicants as a percent of those issued to U.S. citizens, rose from 21 to 45[2]. Capital investment: By 1971 non-residential investment as a percent of GNP had increased to 19.3 in the common market, 31.9 in Japan, 29.1 in the U.S.S.R. and stood at 13.1 in the U.S.[3] Productivity: In the 1965-1971 period, annual growth of GNP per civilian employed had increased to 4.3 percent in six West European countries and the U.S.S.R., to 9.6 percent in Japan, and had declined to 1.3 percent in the U.S.[3] Private supported commercial R&D: In the period 1963 - 1967 civilian-equivalent R&D per dollar GNP in the Common Market and Japan had risen to 122 percent of that in the U.S.[2] Net technological exports: Between 1960 and 1972 the excess of receipts over payments by U.S. companies for technological royalties and license fee increased from $314 million to $1,591 million[2].

2. Boretsky, M., "Trends in U.S. Technology: A Political Economists View", American Scientist, Vol. 63, Jan-Feb 1975, pp. 70-82.

3. Boretsky, M., "U.S. Technology: Trends and Policy Issues", Monograph No. 17, Program of Policy, Studies in Science and Technology", The George Washington University, Washington, D. C., Oct 73.

Together with Vietnam, the energy crisis, and environmental problems, the U.S. technological fading has been a major cause of U.S. economic and political deterioration now generally apparent. Continuation of this drift points toward worsening deficits in trade and the balance of payments, decline in employment opportunities, weakening of the dollar on external markets, increasing protectionist sentiment at home, and further damage to U.S. leadership. Domestically the lag in productivity growth combined with inevitably rising expectations will tend to produce inflationary pressures, pressures for income redistribution and stagnation or decline in the quality of life.

Referring to technology export as a particularly important case in point, a survey discloses a proliferation of separate agencies and mechanisms for processing information release:

(1) The State Department through its Office of Munitions Control is nominally the central coordinating agency of the government in granting licenses for technology export. However, any or all of the following agencies may also be called upon or invite itself, to participate in a licensing decision: Department of Defense, Commerce, Treasury, Transportation, Labor Energy, the Export-Import Bank, NASA and others.

(2) Data, materials and equipment subject to "munitions control" are defined in a regulation of the U.S. code called "International Traffic in Arms Regulation" (ITAR). The broad wording of the ITAR "munitions list" (and of its exemption provisions) permits a wide range of restrictivity or permissiveness according to the interests of whoever happens to be involved in a particular decision.

(3) The Department of Commerce has its own separate export regulations and lists.

(4) The Department of Defense and services have well-established procedures for controlling release of classified information, but decisions often rest on individual judgments.

(5) Presidential executive orders exist which aim at more coherent procedures, and successive administrations have taken widely varying policy positions.

(6) Industrial internal guidelines on technology export are often vague and self-serving.

(7) Academic people frequently find themselves virtually free of restrictions with regard, for example, to presenting papers at foreign and international meetings.

In such an environment the spontaneous emergence of a coherent national technology policy and its concerted implementation cannot be expected. Neither can the U.S. expect to maintain its competitive edge over the decades which will be required for Space Industrialization. Resolution of these problems, which are of the broadest national scope, requires careful and deliberate action by the Federal Government with the assistance of the industrial and intellectual communities, to review and restructure national technology management at the policy, organizational and procedural levels.

Potential contents of a national technology policy might parallel the above outline. Also, it is fairly obvious that there should be an institutional focal point of continuous responsibility within the executive branch for the state of technology in the economy at large, statutorily empowered to initiate new policies as well as to update old policies according to evolving needs. The U.S. alone of all major and industrialized nations, has no such focal point.

How to administer such policies is not so obvious. It seems clear that some degree of centralization is necessary, but it is not clear how much. What seems to be needed in addition to a national technology policy and a focal point for its articulation and evolution, is a system of administration that involves the key elements of government, industry, the military and the intellectual community in a way that will work in a free society.

The necessary involvement of the Federal Government in the funding, application and control of technology in general, and aerospace technologies in particular because of the scale of efforts involved, raises classical questions regarding the relative roles of the public and private sectors in carrying forward the processes of Space Industrialization.

Space Industrialization presents many additional natural impeti toward government control and intervention.

The complex international legal implications of space activities is only just beginning to be formulated and understood, and governments with consultation from their professional legal communities will have to interact on official levels to work out an evolving body of agreements, regulations and treaties. Governments and their armed forces must be responsible for necessary military operations to protect the security of industrial investments and assets located in space. Recent development of "killer" satellites by the U.S.S.R. and reactive U.S. programs give reason for uncertainty and uneasiness in this area. Governments, as was the case in formation of the Comsat Corp., will likely take lead roles in creating policies and organizational forms under which SpaceIndustrialization will be pursued. Prominent examples of activities requiring regulation on the Federal level are reconnaissance and remote sensing data gathering and distribution, broadcast satellite policy, and communications frequency allocation. All of these are information handling activities representing some of the earliest forms of Space Industrialization, and thus are of immediate pressing concern. Governments must be responsible for regulation in questions of environmental impact such as atmospheric effects from energy-producing satellites and exhausts from flight vehicles. Governments traditionally regulate in areas of product and occupational safety, testing and product refinement, all key considerations in generating space industrialization knowhow.

Considerations such as these have led to extreme suggestions that the industrial utilization of space should be left entirely to the government, and should be undertaken as a centralized, systematic large scale project under a government-owned corporation such as the TVA.[4] One limitation of this analogy is that the U.S. is not in nor does it seem to be headed for a Great Depression such as helped lead to the TVA experiment. General sentiment would instead appear more inclined toward efforts to prevent Space Industrialization becoming the back yard of big government. There are many precedents and trends within government for subsidization of large new activities of this sort, often with disappointing results. Subjected to

4. Grodzka, P., "A Space Utilization Authority (SUA) Could be the TVA of the Future", presented at Southeast 2001: The Next 25 Years, Georgia State University, Atlanta, GA, Nov.12-13,76.

ill-directed subsidization, Space Industrialization could drift into the position of being spawned by and spawning, false economics.

A more plausible approach might be establishment of semi-private/ government corporations along the lines of Comsat in key areas of space industry, let them perform the pump-priming function, after which each appropriate area would be opened to progressively freer competition. New technologies and products always threaten some organizations and individual interests. Thus, competitive interactions between sectors and organizations can be expedited as space industrialization matures, and it may be to the general interest for government to remain sufficiently in the operational mode to help regulate and guide this interplay.

At the other end of the spectrum, it may be possible to form publicly owned organizations which can coordinate and catalyse research and technology activities of groups of companies so as to facilitate the development of Space Industrialization in particularly promising directions.

If history is to serve as any guide, then the most likely and effective institutional arrangements, among the non-Communist nations, may be a mix of government, hybrid and private organizations acting more or less in concert.

5.2 FIVE SIGNIFICANT CONSIDERATIONS

As implied by the discussion in Section 5.1 a host of institutions ranging from religious to technological will be affected by Space Industrialization. Their influences on the growth of SI and the specific opportunities which will be capitalized on vary greatly, of course. From discussions with industry contacts, investors, lawyers and national politicians there emerged a basic set of considerations which form the back drop for detailed analysis of key institutional implications.

These items, termed "Five Significant Considerations", are illustrated in Figure 5-1. The five can be expressed as follows:

1. Space industrialization must become an integral part of national space policy planning.

2. Industrializing organizations and legal structures must evolve and be encouraged.

3. Mechanisms for advantageous transfer of responsibility necessary.

4. The applicability of SI technologies to many problems, needs and markets will go unnoticed without focused dialog.

5. The knotty issues of today in technology export will be further driven by the international/multinational nature of SI.

Space industry activities in existence today have already addressed the five items to whatever degree was necessary to achieve implementation. Some proposed industry activities are in transitional phases and some have been stagnated awaiting institutional and policy changes. In the environment of applications oriented space endeavors in the US and the world it would appear that Space Industrialization will represent an increasing fraction of total non-military space expenditures, probably 80 to 90 percent in the early 1980s. Thus it would seem imperative that the overarching concepts of Space Industrialization must be factored into the planning, implementation and exploitation of all new future space capabilities.

The government/industry/academic institutional arrangements necessary to accomplish tasks 1 through 3 and optimize benefit from 4 and 5 must be designed in a fashion responsive to the needs of individual SI initiatives. The first steps can be taken, however, by establishing a planning office responsible for the integration of Space Industrialization elements into all national space activities and plans. This office could supply the data for decisions on items 4 and 5 and formulate plans and focus for accomplishing items 2 and 3 as well as continually project, monitor and assess the implications to a broad family of institutions. Such data should prove invaluable to government and private decision makers alike.

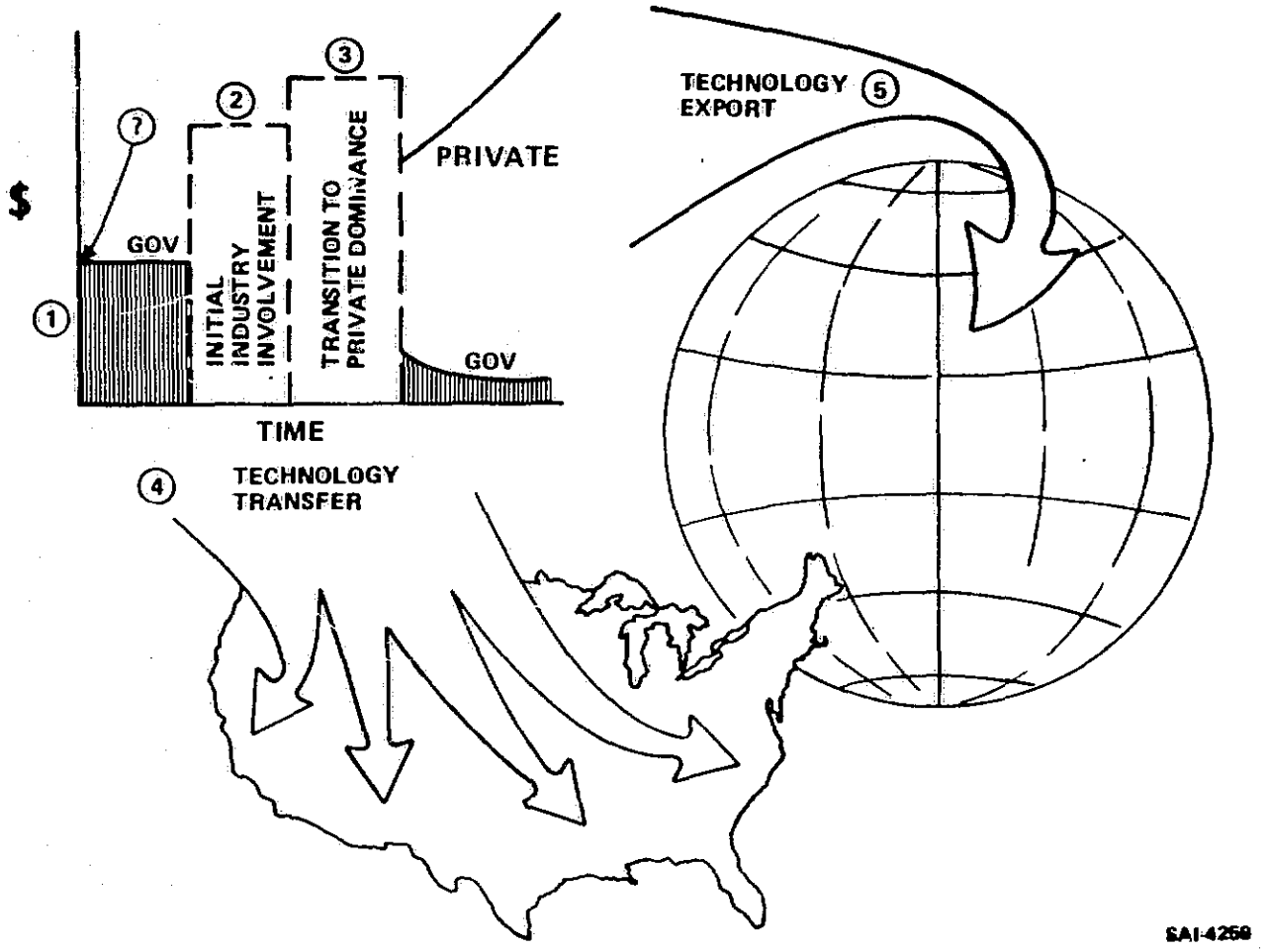


Figure 5-1. Five Significant Considerations

6. CAPITAL REQUIREMENTS AND ECONOMIC VIABILITY

From the revenue analyses reported in Volume 2 of this report it appeared that substantially increased interest in SI might be forthcoming in the investment community. Such interest would result not only from revenue potential but also from initial investment, cash flow, pay back time, project rate of return and similar considerations. Although such analyses were desirable in all industrial areas considered (Information Services, Energy, Products and People in Space) certain limitations and pertinent factors had to be recognized. Specifically, the rapid developments in evaluations of the economics of space based power, the lack of detailed knowledge on product characteristics, and the dependence of People in Space activities on development of other industries precluded reasonable economic assessments in this study. Thus Information Services was the industrial area selected for assessment of these more detailed economic factors.

Five initiatives in Information Services represent over 90% of the potential domestic revenue from space in Information Services (see Section 5.8, Vol 2). These are:

1. Portable Telephone
2. Teleconferencing
3. National Information Service
4. Direct Broadcast TV
5. Electronic Mail

The large potential market for these services was taken as a natural indicator of private investment potential. A major revision to the projections given in Section 5 of Volume 2 was undertaken in Electronic Mail. Whereas the previous analysis assumed legislation or circumstances would dictate that almost all first class mail would go electronic, this revision limited the quantity to current simple sheet volumes. Thus bills, checks and similar business matter would still go by original delivery. The results of this revision are presented in the next section.

6.1 MARKET POTENTIAL DETERMINATION: ELECTRONIC MAIL (REVISION 1)

Using simple sheet mail only as the criteria, the market potential for electronic mail was defined to be 6 billion pieces in the 1984/85 time period. This quantity was defined by Rockwell International in the companion study to this one and its derivation is discussed in their Final Report on Space Industrialization. With two sheets per piece, this means a market of 12 billion sheets. The Rockwell study assumes a declining number of letters posted through the Post Office which contradicts present trends of increasing volume. Assume, therefore, a constant number of users (the decline being offset by the increase in population and general communications needs in the US).

Two major situations could arise in the use of satellites by the Post Office. First, about 100 postal centers handle half the mail volume in the US. There are 30,000 postal centers in total. Electronic mail could be restricted to those 100 centers, or could be expanded to include all 30,000 (with the obvious compromise of coming somewhere in between). In the first case, we could assume a rapid saturation - on the order of five years - to bring the 100 centers on line with the electronic service. The second case would take longer, if only because of the logistics. Assume 10 years before full service is instituted at all centers. Further, assume a user charge in either case of 10¢ per sheet, held constant (assuming constant dollars) over the time period - beginning in 1990.

The resulting revenues are summarized in Table 6-1.

6.2 GROUNDRULES AND ASSUMPTIONS

Specific assumptions will be given in the following sections which present the approach and data for each step of the economic analyses. The general groundrules and assumptions which apply to all assessments are as follows:

1. All hardware, deployment and space operations costs were provided by Rockwell International through their Space Industrialization Study which was companion to the SAI study. Details of the derivation are contained in their report.

TABLE 6-1. REVISED REVENUE POTENTIAL FOR ELECTRONIC MAIL AT A REDUCED ANNUAL VOLUME OF 12 BILLION PIECES

100 Centers

	Sheet Volume (1st Class)	User %	User Mail	Cost	Revenue
1990	12B	20% (50%)	1.2B	10¢	$120M
1991		40%	2.4B		240M
1992		60%	3.6B		360M
1993		80%	4.8B		480M
1994		100%	6.0B		600M
1995			6.0B		600M
2000			6.0B		600M
2010			6.0B		600M

30000 Centers

	Sheet Volume (1st Class)	User%	User Mail	Cost	Revenue
1990	12B	3.3%	0.4B	10¢	$40M
1991		6.7%	0.8B		80M
1992		10.0%	1.2B		120M
1993		30%	3.6B		360M
1994		50%	6.0B		600M
1995		70%	8.4B		840M
1996		90%	10.8B		1080M
1997		93.3%	11.2B		1120M
1998		96.7%	11.6B		1160M
1999		100%	12.0B		1200M
2000			12.0B		1200M
2010			12.0B		1200M

2. The large power system (500 KW) associated with the platform carrying the five services will be partially developed as a Satellite Power System (SPS) demonstration article. A 50% reduction (about 150 million dollars) in initial development cost was assumed as funded by DOE.

3. The size of the space system and its production costs are linearly related to the required communications channels.

4. A company infrastructure sufficient to implement the ground related systems (including management, accounting, etc.) already exists and has characteristics similar to current business operations.

5. Market penetration rates and specific events in the implementation phase for all five services will correspond roughly to the Baseline Scenario as discussed in Volume 2.

The first multi-use Geosynchronous Platform to provide market entry into the five services is shown in Figures 6-1 and 6-2 (courtesy of Rockwell International). This design provided the basis for development and initial operational cost assessment as the markets develop into the 1990s and beyond larger versions of the same type system were assumed.

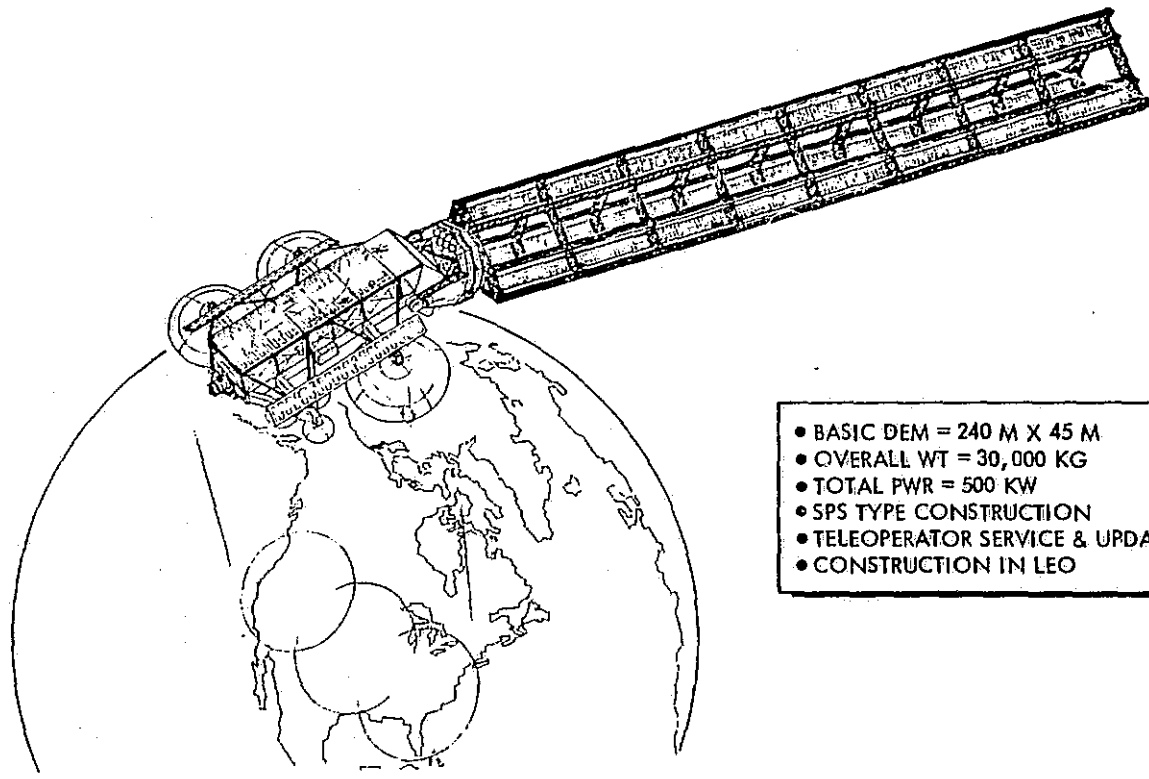
The specific functions provided by this early satellite are as follows:

1. Direct broadcast television - Five simultaneous color video channels 16 hours per day to be received on modified, conventional TV receivers. The entire CONUS area is to be covered (excluding Alaska, Hawaii, and Puerto Rico).

2. Pocket telephones - Multiple voice channels originating from remote, wireless extensions; to be connected to conventional fixed terminals, or other remote terminals via satellite. Saturation capacity to be at least 45,000 simultaneous transactions.

3. National information services - Direct access via satellite from home or business *intelligent terminals* to computer-supported data banks, such as the Library of Congress.

4. Teleconferencing - Two-way (or multiple) video links between as many as 300 ground sites simultaneously (150 conferences). User



- BASIC DEM = 240 M X 45 M
- OVERALL WT = 30,000 KG
- TOTAL PWR = 500 KW
- SPS TYPE CONSTRUCTION
- TELEOPERATOR SERVICE & UPDATE
- CONSTRUCTION IN LEO

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Rockwell International
Space Division

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Figure 6-1. 500 KW Geosynchronous Platform

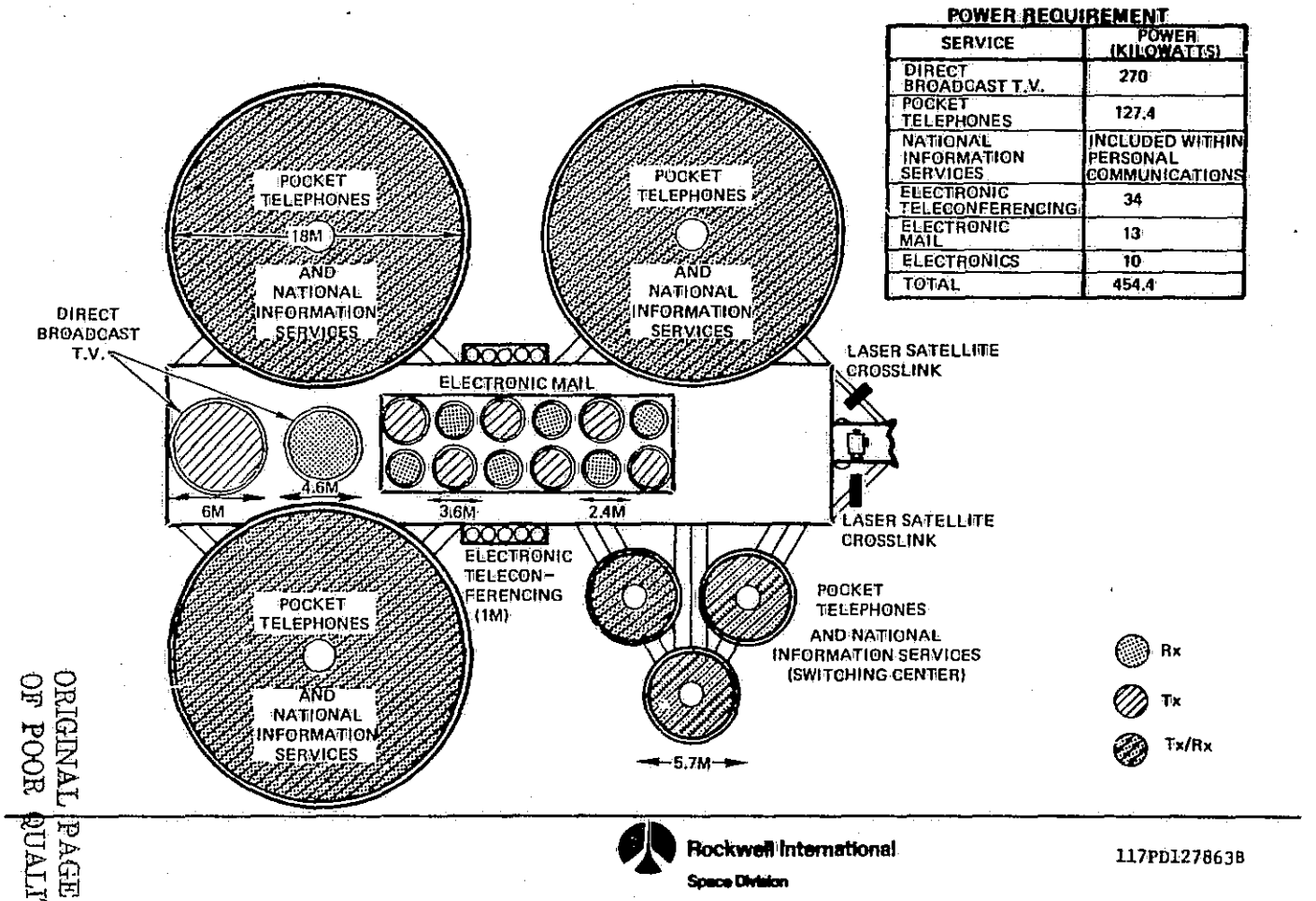


Figure 6-2. Antenna Locations for the Geosynchronous Platform

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locations would have studio-type facilities, including multiple cameras and monitors, switch gear, and communications.

5. Electronic Mail - Facsimile transmission of personal and business correspondence. Terminals would be located in regional postal centers. The regional centers would be interconnected via satellite. Each regional postal center would contain equipment to convert hard copy to electronic facsimile, and vice versa. The ultimate goal is to deliver 40 million pages (8½ x 11) from source to destination over night.

6.3 METHODOLOGY

In sizing up cash flow and project rate of return, certain types of data were essential. Among these were profit margin as a function of total revenue and number of channels needed to meet system demand. The number of channels determine total system cost. Each system as designed has a capacity for a certain number of channels. As demand for the service grows, the system must increase channel capacity. This is generally accomplished by adding more equivalent satellites - which adds to overall cost. Total cost over time can then be found.

Once total revenue from a system was determined, it was necessary to find net profit. This was done by analogy with existing companies of a nature similar to that which would be offering satellite services. Reaching a percentage rate of total revenue, the resultant net profit from the satellite service was then used to get overall cash flow by comparing total system cost with net income over time, and determining net positive or negative cash flow by year.

A specific investment decision tool was chosen for evaluation of economic viability assuming all costs are borne by the operating company other than the DOE development credit discussed earlier. The tool chosen is known as "Project Rate of Return" or "Discounted Cash Flow Method".[1] This approach finds the earnings rate at which the present value of the earnings equals the amount of the investment. Values greater than 10% for project rate of return are considered potentially good investments.

1. Management Accounting Principles, Robert N. Anthony

6.4 RESULTS OF ASSESSMENT STEPS

The following sections present the results obtained in the individual steps discussed above.

6.4.1 Number of Channels Needed in a National Teleconferencing Net

Assume 250 business days per year (which excludes holidays and weekends). Assume 8 hours per business day. And assuming very few conferences will be shorter than 1 hour; very few longer than 8 hours; then assume a 2 hour average conference length.

This information is derived from Market Potential: 3-D Holographic Teleconferencing (Volume 2).

Users

	Population	Saturation	User group (least)	User group (best)
1990	24350K	1.5% (10%)	36K	180K
1991	25000K	3%	75K	375K
1992	25650K	4.5%	115K	575K
1993	26300K	6%	158K	790K
1994	26950K	7.5%	202K	1010K
1995	27600K	9%	248K	1240K
1996	28250K	10%	282K	1410K
1997	28900K	20%	578K	2890K
1998	29550K	30%	886K	4430K
1999	30200K	40%	1208K	6040K
2000	30850K	50%	1542K	7710K
2001	31500K	60%	1890K	9450K
2002	32150K	70%	2250K	11250K
2003	32800K	80%	2624K	13120K
2004	33450K	90%	3010K	15050K
2005	34100K	91.5%	3120K	15600K
2006	34750K	93%	3232K	16160K
2007	35400K	94.5%	3345K	16725K
2008	36050K	96%	3461K	17305K
2009	36700K	97.5%	3578K	17890K
2010	37350K	99%	3698K	18490K

Channels Required

	Least	Average	Best
1990	36	108	180
1991	75	225	375
1992	115	345	575
1993	158	474	790
1994	202	606	1010
1995	248	744	1240
1996	282	846	1410
1997	578	1734	2890
1998	886	2658	4430
1999	1208	3624	6040
2000	1542	4626	7710
2001	1890	5670	9450
2002	2250	6750	11250
2003	2624	7872	13120
2004	3010	9030	15050
2005	3120	9360	15600
2006	3232	9696	16160
2007	3345	10035	16725
2008	3461	10383	17305
2009	3578	10734	17890
2010	3698	11094	18490

6.4.2 Number of Channels Needed in a National Personal Communications Net

Assume 365 user days per year. Assume 15 user hours per day. Assume 5 minutes per average call.

This information is derived from Market Potential Determination Portable Telephone (Volume 2).

	Calls (least)	Calls (best)	Channels (Least)	Channels (Avg)	Channels Best
1995	17.3M	40.1M	263	436	610
1996	56.9M	128.5M	866	1411	1956
1997	107.7M	242.7M	1639	2666	3694
1998	173.0M	389.8M	2633	4283	5933
1999	252.9M	572.3M	3849	6280	8711
2000	350.4M	803.0M	5333	8777	12222
2001	459.9M	1058M	7000	11551	16103
2002	642.4M	1481M	9778	16160	22542
2003	788.4M	1826M	12000	19896	27793
2004	949.0M	2206M	14444	24010	33577
2005	2095M	2621M	31889	35891	39893
2006	3339M	6148M	50832	72204	93577
2007	4788M	10471M	72889	116132	159376
2008	6391M	15717M	97277	168250	239224
2009	8212M	21832M	125000	228649	332298
2010	10125M	28870M	154111	206766	439422

6.4.3 Number of Channels Used by Business in a National Information Service (Volume 2).

Assume 8 hours (480 minutes) per business day. Assume 100 user minutes per day for businesses with assets greater than $1 Million (large). Assume 10 user minutes per day for other businesses (small).

(Large businesses)

	User group (low)	User group (high)	Channels (low)	Channels (high)
2000	5.7K	11.4K	1.1K	2.3K
2001	11.9K	23.8K	2.4K	4.8K
2002	18.1K	36.2K	3.6K	7.2K
2003	55.6K	111.2K	11.1K	22.2K
2004	94.7K	189.4K	18.9K	37.9K
2005	135.4K	270.8K	27.1K	54.2K
2006	177.7K	355.4K	35.5K	71.1K
2007	188.0K	376.0K	37.6K	75.2K
2008	198.7K	397.4K	39.7K	79.5K
2009	209.5K	419.0K	41.9K	83.8K
2010	213.5K	427.0K	42.7K	85.4K

(Other businesses)

	User group (low)	User group (high)	Channels (low)	Channels (high)
2000	14.5K	36.2K	.3K	.7K
2001	30.1K	75.2K	.6K	1.5K
2002	46.0K	115.0K	.9K	2.3K
2003	141.0K	352.5K	2.8K	7.0K
2004	240.0K	600.0K	4.8K	12.0K
2005	343.0K	857.5K	6.9K	17.1K
2006	450.0K	1125.0K	9.0K	22.5K
2007	475.8K	1189.5K	9.5K	23.8K
2008	502.8K	1257.0K	10.0K	25.1K
2009	530.0K	1325.0K	10.6K	26.5K
2010	540.0K	1350.0K	10.8K	27.0K

Total Channels

	Low	High
2000	1.3K	3.0K
2001	3.0K	6.3K
2002	4.5K	9.5K
2003	13.9K	29.2K
2004	23.7K	49.9K
2005	34.0K	71.3K
2006	44.5K	93.6K
2007	47.1K	99.0K
2008	49.7K	104.6K
2009	52.5K	110.3K
2010	53.5K	112.4K

6.4.4 Profit Margins as a Function of Total Revenue

In the 1977 volume of Moody's Public Utility Manual and Moody's Industrial Manual, the following profit margins (as a function of total (revenue) were obtained:

AT&T	11 - 13%	(13% to 16% in prior years, as 1964-1970)
Comsat	18 - 34%	
GT&E (Service only)	11%	
(Service + products . . . consolidated)	4 - 7%	
IBM	13 - 15%	
Western Union	6 - 10%	(9%to 10% most recently)

These companies represent some of the leading communications and electronics companies in the country. Their margins represent typical margins which could be expected for a future space communications company. However, Comsat's margins - quite a bit higher than the rest - are currently under review by the FCC, and could be significantly reduced. Further, if the rates are reduced, Comsat will be required to repay to former customers the balance of what they would have paid versus what they actually did pay. Therefore, the margins for Comsat would not likely be relevant to a long term margin situation for a regulated space communications company, as we could expect one to be. For this purpose, then, Comsat's numbers will be disregarded.

GT&E numbers were available for both service alone (which includes operating revenues from billings for telephone services), and for services consolidated with manufacturing operations. As a service company, GT&E is significantly more profitable (11% margin) than as a service and manufacturing company (4% - 7%). This, plus the extremely high margins for Comsat (basically a service company) seem to imply that a future space communications company could do best by concentrating on services - leaving the manufacture of product essentially to other companies.

For the purposes of this study, apply these rates (6% to 15%) to
Electronic Mail (Table 6-2)
National Teleconferencing (Table 6-3)
Portable Telephone (Table 6-4)
National Information Service (Table 6-5)
Direct Broadcast TV (Table 6-6)

According to the 1977 volume of Moody's Public Utility Manual, consolidated AT&T operating expenses (less depreciation and maintenance)

TABLE 6-2.

ELECTRONIC MAIL

(Least Case: 100 Centers)

	Revenue	6%	15%
1990	$120M	$7.2M	$18.0M
1991	240	14.4	36.0
1992	360	21.6	54.0
1993	480	28.8	72.0
1994	600	36.0	90.0
1995	600	36.0	90.0

2000	600	36.0	90.0

2010	600	36.0	90.0

(Best Case: 30000 Centers)

	Revenue	6%	15%
1990	$40M	$2.4M	$6M
1991	80	4.8	12
1992	120	7.2	18
1993	360	21.6	54
1994	600	36.0	90
1995	840	50.4	126
1996	1080	64.8	162
1997	1120	67.2	168
1998	1160	69.6	174
1999	1200	72.0	180
2000	1200	72.0	180

2010	1200	72.0	180

TABLE 6-3

TELECONFERENCING

(Least Case)

	Revenue	6%	15%
1990	$18.3M	$1.1M	$2.7M
1991	37.5	2.2	5.6
1992	57.7	3.5	8.6
1993	78.9	4.7	11.8
1994	101.1	6.1	15.2
1995	124.2	7.4	18.6
1996	141.2	8.5	21.2
1997	289.0	17.3	43.3
1998	443.2	26.6	66.5
1999	604.0	36.2	90.6
2000	771.2	46.3	115.7

2005	1548.5	92.9	232.3

2010	1842.5	110.5	276.4

(Best Case)

	Revenue	6%	15%
1990	$91.5M	$5,5M	$13.7M
1991	187.5	11.2	28.1
1992	288.5	17.3	43.2
1993	394.5	23.7	59.2
1994	505.5	30.3	75.8
1995	621.0	37.2	93.1
1996	706.0	42.4	105.9
1997	1445.0	86.7	216.7
1998	2216.0	133.0	332.4
1999	3020.0	181.2	453.0
2000	3855.0	231.3	578.2

2005	7748.0	464.9	1162.2

2010	9212.5	552.7	1381.9

TABLE 6-4

PERSONAL COMMUNICATION (PORTABLE TELEPHONE)

(Least Case)

	Revenue	6%	15%
1995	$51.9M	$3.1M	$7.8M
1996	125.2	2.5	18.8
1997	193.9	11.6	29.1
1998	276.8	16.6	41.5
1999	361.6	21.7	54.2
2000	459.0	27.5	68.8
2001	561.1	33.7	84.2
2002	745.2	44.7	111.8
2003	859.3	51.5	128.9
2004	977.5	58.6	146.6
2005	2053.3	123.2	308.0
2006	2337.8	140.3	350.7
2007	2681.7	160.9	402.2
2008	3067.7	184.1	460.1
2009	3531.4	211.9	529.7
2010	3948.8	236.9	592.3

(Best Case)

	Revenue	6%	15%
1995	$120.4M	$7.2M	$18.1M
1996	282.7	17.0	42.4
1997	436.9	26.2	65.5
1998	623.7	37.4	93.5
1999	818.4	49.1	122.8
2000	1052.	63.1	157.8
2001	1290.	77.4	193.5
2002	1718.	103.1	257.7
2003	1991.	119.5	298.6
2004	2272.	136.3	340.8
2005	2569.	154.1	385.2
2006	4304.	258.2	645.6
2007	5235.	314.1	785.2
2008	7544.	452.6	1131.6
2009	9388.	563.3	1408.2
2010	11259.	675.5	1688.8

TABLE 6-5

NATIONAL INFORMATION SYSTEM

(Least Case)

	Revenue	6%	15%
1990	$2.4M	$0.1M	$0.4M
1991	4.7	0.3	0.7
1992	7.1	0.4	1.1
1993	21.3	1.3	3.2
1994	35.5	2.1	5.3
1995	49.7	3.0	7.4
1996	63.9	3.8	9.6
1997	66.3	4.0	9.9
1998	68.6	4.1	10.3
1999	71.0	4.3	10.6
2000	142.5	8.5	21.4
2001	220.1	13.2	33.0
2002	298.0	17.9	44.7
2003	768.0	46.1	115.2
2004	1258.0	75.5	188.7
2005	1768.0	106.1	265.2
2006	2298.0	137.9	344.7
2007	2426.8	145.6	364.0
2008	2560.8	153.6	384.1
2009	2696.0	161.8	404.4
2010	2746.0	164.8	411.9

(Best Case)

	Revenue	6%	15%
1990	$3.2M	$0.2M	$0.5M
1991	6.7	0.4	1.0
1992	10.0	0.6	1.5
1993	29.9	1.8	4.5
1994	49.9	3.0	7.5
1995	69.9	4.2	10.5
1996	89.8	5.4	13.5
1997	93.1	5.6	14.0
1998	96.5	5.8	14.5
1999	99.8	6.0	15.0
2000	250.0	15.0	37.4
2001	413.0	24.8	61.9
2002	576.8	34.6	86.5
2003	1464.3	87.8	219.6
2004	2593.8	155.6	389.1
2005	3665.3	219.9	549.8
2006	4778.8	286.7	716.8
2007	5049.3	302.9	757.4
2008	5330.8	319.8	799.6
2009	5614.8	336.9	842.2
2010	5719.8	343.2	858.0

TABLE 6-6

DIRECT TELEVISION

(Least Case)

	Revenue	6%	15%
2000	$14.5M	$0.9M	$2.2M
2001	29.4	1.8	4.4
2002	44.5	2.7	6.7
2003	60.0	3.6	9.0
2004	75.7	4.5	11.3
2005	91.8	5.5	13.8
2006	103.0	6.2	15.4
2007	208.0	12.5	31.2
2008	315.0	18.9	47.2
2009	424.0	25.4	63.6
2010	535.0	32.1	80.2

(Best Case)

	Revenue	6%	15%
2000	$97.M	$5.8M	$14.5M
2001	196.	11.8	29.4
2002	297.	17.8	44.5
2003	400.	24.0	60.0
2004	505.	30.3	75.7
2005	612.	36.7	91.8
2006	721.	43.3	108.1
2007	832.	49.9	124.8
2008	945.	56.7	141.7
2009	1060.	63.6	159.0
2010	1930.	115.9	289.5

range from $40 to $80 per phone installed. Before high inflation rates (1950-1960), operating expenses hovered in the range of $40 per phone. During the 1950 decade, total number of telephones in operation increased from 35 million to 61 million. By 1976, this number had doubled again to 123 million.

This implies to a future phone net (such as portable telephone) that operating costs will be on the order of less than $100 per unit, but that over a certain (high) number of operational units, operational expenses may begin to increase rapidly on a per unit basis. In any case, to be realistic, anticipated revenues must exceed the approximate number of $100 per unit per year.

6.4.5 Rate of Return and Cash Flow Analysis

6.4.5.1 Groundrules

Where additional systems are needed, a 95% learning curve is assumed with respect to the first system cost, to allow for development of new technologies. This does not apply to transportation costs.

Transport costs are assumed to be as given by RI until 1990, then halved from 1991 to 2000, and halved again from 2001 to 2010.

All costs are constant dollars, as are income figures.

Although RI figures are time specific, we will assume that the major costs (aside from transport) are time independent - applicable as given to any period within the study limits (as subsequently biased by learning curve effects).

Best case and worst case net income estimates will assume a 15% margin of revenue, as representing a good approximation for a satellite company operating as a service company only.

Operations costs are subsumed in the net income figures.

Where two equivalent systems are needed to satisfy demand, costs are doubled.

Investment cash streams are discounted at a 10% rate to take into account the relatively high risk of the projects.

6.4.5.2 Personal Communications

The Personal Communications system can handle 45,000 simultaneous conversations. This means that although the system needs may be growing with time, the system itself can handle a good number of calls, thus precluding any extremely large investment for a great number of systems. The worst case situation could see a demand for about 155,000 channels by the year 2010; the best case could see a demand for about 440,000. In the best case, this could mean an equivalent of two systems put up in a given year during the main growth phase.

Undiscounted cash flow analysis shows a break even in 15 years for the worst case, and 11 years for the best case. Project rate of return is 12% for the worst case, 14% for the best case. This implies a moderately healthy investment situation, with a good set of potential revenue figures.

Cash Flow (Best Case)

	Acquisition				Transport		Net Income	Net Cash Flow
1990	$16.8M							($16.8M)
1991	82.0							(98.8)
1992	133.2							(232.0)
1993	123.5							(355.5)
1994	50.1					$10.9M		(416.5)
1995							$18.1M	(398.4)
1996							42.4	(356.0)
1997							65.5	(290.5)
1998							93.5	(197.0)
1999							122.8	(74.2)
2000							157.8	83.6
2001	19.2						193.5	257.9
2002	93.4	9.1					257.7	413.1
2003	151.8	44.3	17.1				298.6	498.5
2004	140.8	71.9	83,6	16.5			340.8	526.5
2005	57.0	66.7	135.9	80.4	15.4	10.9	385.2	545.4
2006	14.8	27.0	126.0	130.5	75.4	5.5	645.6	811.8
2007	72.2	14.1	51.1	121.0	122.5	10.9	785.2	1205.2
2008	117.2	68.9	13.4	49.1	113.6	10.9	1131.6	1963.7
2009	108.7	111.9	65.6	12.8	46.1	10.9	1408.2	3015.9
2010	44.1	103.7	106.6	62,3	12.1	10.9	1688.2	4364.4

Cash Flow (Worst Case)

	Acquisition			Transport	Net Income	Net Cash Flow
1990	$16.8M					($16.8M)
1991	82.0					(98.8)
1992	133.2					(232.0)
1993	123.5					(355.5)
1994	50.1			$10.9M		(416.5)
1995					$7.8M	(408.7)
1996					18.8	(389.9)
1997					29.1	(360.8)
1998					41.5	(319.3)
1999					54.2	(265.1)
2000					68.8	(196.3)
2001	9.6				84.2	(121.7)
2002	46.7				111.8	(56.6)
2003	75.9	8.6			128.9	(12.2)
2004	70.4	41.8			146.6	22.2
2005	28.5	67.9	7.7	5.5	308.0	220.6
2006		63.0	37.7		350.7	470.6
2007	7.0	25.5	61.3	5.5	402.2	773.5
2008	34.4		56.8		460.1	1142.4
2009	55.9	6.4	23.0	5.5	529.7	1581.3
2010	51.9	31.1			592.3	2090.6

This assumes some startups before 2010 for services beginning after 2010.

6.4.5.3 Advanced TV Broadcast

Assume the growth of the market implies a need for a growing number of channels. Thus every 10 years we might see a new system capable of retransmitting an increased number of channels. The new system can be justified either on the basis of new channels requirements, or lifetime expectancy rates. The first system begins development in 1996 and becomes operational in the year 2000. The second system begins operation in 2010.

			Net Income		Net Cash Flow	
	Acquisition	Transport	Worst Case	Best Case	Worst Case	Best Case
1996	$14.7M				($14.7M)	($14.7M)
1997	63.1				(77.8)	(77.8)
1998	80.2				(158.0)	(158.0)
1999	36.5	$5.5M			(200.0)	(200.0)
2000			$2.2M	$14.5M	(197.8)	(185.5)
2001			4.4	29.4	(193.4)	(156.1)
2002			6.7	44.5	(186.7)	(111.6)
2003			9.0	60.0	(177.7)	(51.6)
2004			11.3	75.7	(166.4)	24.1
2005			13.8	91.8	(152.6)	115.9
2006	8.8		15.4	108.1	(146.0)	215.2
2007	37.9		31.2	124.8	(152.7)	302.1
2008	48.1		47.2	141.7	(153.6)	395.7
2009	25.2	2.8	63.6	159.0	(118.0)	526.7
2010			80.2	289.5	(37.8)	816.2

(Best Case)

Undiscounted cash flow gives a break even in 9 years. Project rate of return is approximately 17%, over a period of 15 years.

(Worst Case)

Cash flow shows a continuing loss over the horizon time period given. Project rate of return is negative.

6.4.5.4 National Information Service

One system will be needed to take care of the needs of libraries (beginning in 1990). Another system will be needed to take care of the needs of business. Assuming the same system as Personal Communications, then 45,000 2-way channels are available from each satellite. Worst case, then, would require a satellite in each of the following years: 1990, 2000, 2007. Best case would require a satellite in the following years: 1990, 2000, 2004, 2006.

Undiscounted cash flow shows break even in 21 years (best case) and 22 years (worst case). Rate of return is 12% (best case) and 9% (worst case).

NATIONAL INFORMATION SERVICE

Cash Flow (Best Case)

	Acquisition		Transport	Net Income	Net Cash Flow
1985	$16.8M				($16.8M)
1986	82.0				(98.8)
1987	133.2				(232.0)
1988	123.5				(355.5)
1989	50.1		$10.9M		(416.5)
1990				$0.5M	(416.0)
1991				1.0	(415.0)
1992				1.5	(413.5)
1993				4.5	(409.0)
1994				7.5	(401.5)
1995	10.6			10.5	(401.6)
1996	51.7			13.5	(439.8)
1997	83.9			14.0	(509.7)
1998	77.8			14.5	(573.0)
1999	31.6	$8.6M	5.5	15.0	(603.7)
2000		41.8		37.4	(608.1)
2001	7.7	67.9		61.9	(621.8)
2002	37.7	63.0		86.5	(636.0)
2003	61.3	25.5	2.7	219.6	(505.9)
2004	56.8			389.1	(173.6)
2005	23.0		2.7	549.8	350.5
2006				716.8	1067.3
2007				757.4	1824.7
2008				799.6	2624.3
2009				842.2	3466.5
2010				858.0	4324.5

NATIONAL INFORMATION SERVICE

Cash Flow (Worst Case)

	Acquisition	Transport	Net Income	Net Cash Flow
1985	$16.8M			($16.8M)
1986	82.0			(98.8)
1987	133.2			(232.0)
1988	123.5			(355.5)
1989	50.1	$10.9		(416.5)
1990			$0.4M	(416.1)
1991			0.7	(415.4)
1992			1.1	(414.3)
1993			3.2	(411.1)
1994			5.3	(405.8)
1995	10.6		7.4	(409.0)
1996	51.7		8.6	(451.1)
1997	83.9		9.9	(525.1)
1998	77.8		10.3	(592.6)
1999	31.6	5.5	10.6	(619.1)
2000			21.4	(597.7)
2001			33.0	(564.7)
2002	7.4		44.7	(527.4)
2003	36.1		115.2	(448.3)
2004	58.6		188.7	(318.2)
2005	54.3		265.2	(107.3)
2006	22.0	2.7	344.7	(212.7)
2007			364.0	(576.7)
2008			384.1	(960.8)
2009			404.4	1365.2
2010			411.9	1777.1

6.4.5.5 National Information Service (Modification)

In this modification of the National Information analysis, businesses are no longer assumed to start use of the service ten years after libraries. Instead, it's assumed that they start using the service

at the same time as libraries, in 1990. This effectively increases the number of channels needed in the first ten years, and thereby affects the number of satellites put into orbit, and when. In the worst case, a new system is needed in 1990 and 1995. In the best case, a new system is needed in 1990, 1994, 1995, and 1999.

The resultant breakeven from this change comes in 12 years (worst case) and 11 years (best case). Project rates of return are 15% (worst case) and 17% (best case).

Channels Used

(Worst Case)

Year	Libraries		Business	Total
1990	.2K	.4K	1.4K	2.0K
1991	.4	.7	3.0	4.1
1992	.6	1.1	4.5	6.2
1993	1.8	3.3	13.9	19.0
1994	3.0	5.5	23.7	32.2
1995	4.2	7.7	34.0	45.9
1996	5.4	9.9	44.5	59.8
1997	5.6	10.2	47.1	62.9
1998	5.8	10.6	49.7	66.1
1999	6.0	11.0	52.5	69.5
2000	6.0	11.0	53.5	70.5

(Best Case)

Year	Libraries		Business	Total
1990	.3K	.7K	3.0K	4.0K
1991	.5	1.3	6.3	8.1
1992	.8	2.0	9.5	12.3
1993	2.3	5.9	29.2	37.4
1994	3.9	9.9	49.9	63,7
1995	5.5	13.9	71.3	90.7
1996	7.0	17.8	93,6	118.4
1997	7.3	18.5	99.0	124.8
1998	7.5	19.1	104.6	131.2
1999	7.8	19.8	110.3	137.9
2000	7.8	19.8	112.4	140.0

Cash Flow (Best Case)

	Acquisition		Transport	Net Income	Cum Cash Flow
1985	$16.8M				($16.8M)
1986	82.0				(98.8)
1987	133.2				(232.0)
1988	123.5				(355.5)
1989	50.1	$14.4M	$10.9M		(416.5)
1990	13.6	70.5		$37.9M	(462.7)
1991	66.4	114.5		62.9	(580.7)
1992	107.9	106.2		88.0	(706.8)
1993	100.0	43.1	5.5	224.1	(631.3)
1994	40.6	11.1	5.5	396.6	(291.9)
1995		54.1		560.3	214.3
1996		87.9		730.3	856.7
1997		81.5		771.4	1546.6
1998		33.1	5.5	814.1	2322.1
1999				857.2	3179.3
2000				873.0	4052.3

Cash Flow (Worst Case)

	Acquisition	Transport	Net Income	Cum Cash Flow
1985	$16.8M			($16.8M)
1986	82.0			(98.8)
1987	133.2			(232.0)
1988	123.5			(355.5)
1989	50.1	$10.9M		(416.5)
1990	13.6		$21.8M	(408.3)
1991	66.4		33.7	(441.0)
1992	106.6		45.8	(501.8)
1993	98.8		118.4	(482.2)
1994	40.1	5.5	194.0	(333.8)
1995			272.6	(61.2)
1996			354.3	293.1
1997			373.9	667.0
1998			394.4	1061.4
1999			415.0	1476.4
2000			422.9	1899.3

6.4.5.6 Teleconferencing

Assume that growth of the market implies a need for a growing number of channels to meet market demand. This number will depend on the growth rate of the market - and will vary between best and worst cases. The system as defined can handle 80 simultaneous conferences. The worst case could see about 3700 conferences going on at any one time; the best case could see about 18,500 conferences going simultaneously. This means a very large number of equivalent systems must be put up each year - especially during the growth phase of the market. For best case, this would mean up to 25 in a given year.

(Best Case)

Undiscounted cash flow gives a break even in 19 years. Project rate of return is approximately 11%, over a period of 25 years.

(Worst Case)

Undiscounted cash flow gives a break even in 19 years. Project rate of return is approximately 11%, over a period of 25 years.

TELECONFERENCING

Cash Flow (Best Case)

	Acquisition				Transport	Net Income	Net Cash Flow	Systems
1986	$19.2M						($19.2M)	3
1987	82.2	5.3					(106.7)	2
1988	104.7	22.6	7.6				(241.6)	3
1989	47.7	28.9	32.1	4.8	$21.0M		(376.1)	2
1990	6.8	13.1	41.0	20.2	14.0	$13.7M	(457.5)	3
1991	28.6	6.5	18.6	25.8	10.5	28.1	(519.4)	3
1992	36.5	27.4	4.2	11.7	7.0	43.2	(563.0)	2
1993	16.6	35.0	17.8	39.2	10.5	59.2	(622.9)	20
1994	37.0	15.9	22.8	166.6	10.5	75,8	(799.9)	20
1995	157.1	35.3	10.3	212.8	7.0	93.1	(1129.3)	20
1996	200.6	149.9	33.6	96.6	70.0	105.9	(1574.1)	20
1997	91.1	191.5	142.8	33.6	70.0	216.7	(1886.4)	21
1998	33.3	86.9	182.4	142.8	70.0	332.4	(2069.4)	22
1999	141.6	32.8	82.8	182.4	70.0	453.0	(2126.0)	23
2000	180.9	139.2	34.3	82.8	73.5	578.2	(2058.5)	25
2001	82.1	177.8	145.8	7.8	38.5	708.2	(1802.3)	6
2002	8.7	80.7	186.2	33.3	40.2	843.2	(1308.2)	7
2003	36.9	9.5	84.5	42.6	43.7	983.2	(542.2)	8
2004	47.1	40.5	7.8	19.3	10.5	1128.2	460.8	7
2005	21.4	51.7	33.3	7.6	12.2	1162.2	1496.8	7
2006	8.1	23.5	42.6	32.1	14.0	1206.2	2582.7	8
2007	34.5	7.6	19.3	41.0	12.2	1250.2	3718.3	8
2008	44.1	32.1	7.3	18.6	12.2	1294.2	4898.2	8
2009	20.0	41.0	30.9	7.0	14.0	1338.2	6123.5	8
2010	6.5	18.6	39.5	29.7	14.0	1381.9	7397.1	8

TELECONFERENCING

Cash Flow (Worst Case)

	Acquisition			Transport		Net Income	Net Cash Flow	Systems
1986	$6.4M						($6.4M)	1
1987	27.4						(33.8)	
1988	34.9	2.5					(71.2)	1
1989	15.9	10.7			$7.0M		(104.8)	
1990	2.3	13.7				$2.7M	(118.1)	1
1991	9.6	6.2	2.1		3.5	5.6	(133.9)	1
1992	12.3		9.2			8.6	(146.8)	
1993	5.6		11.7	7.8	3.5	11.8	(163.6)	4
1994	7.4		5.3	33.3	3.5	15.2	(197.9)	4
1995	30.9	7.0		42.6		18.6	(259.8)	4
1996	39.5	29.7	6.7	19.3	14.0	21.2	(347.8)	4
1997	17.9	38.0	28.6	6.4	14.0	43.3	(409.4)	4
1998	7.6	17.2	36.5	27.4	14.0	66.5	(445.6)	5
1999	32.1	5.6	16.6	35.0	14.0	90.6	(458.3)	4
2000	41.0	23.8	6.9	15.9	14.0	115.7	(444.2)	5
2001	18.6	30.4	28.6	1.3	9.0	141.8	(390.3)	1
2002	2.5	13.8	36.5	5.5	7.2	168.9	(286.9)	2
2003	10.5	1.2	16.6	7.0	7.2	197.0	(132.4)	1
2004	13.4	5.0	2.2	3.2	1.8	226.1	68.1	2
2005	6.1	6.4	9.5	1.1	3.6	232.3	273.7	1
2006	2.0	2.9	12.2	4.5	1.8	241.1	491.4	2
2007	8.6	1.9	5.5	5.8	3.6	249.9	715.9	2
2008	10.9	8.1	1.8	2.6	1.8	258.7	949.4	2
2009	5.0	10.3	7.6	1.7	3.6	267.5	1188.7	2
2010	1.6	4.7	9.7	7.4	3.6	276.4	1438.1	2

6.4.5.7 Electronic Mail

Assume that once system saturation is reached, the amount of mail remains steady, and that therefore, a single system is applicable. If such a system has a lifetime of 20 years, then if the first satellite begins operation in 1990, the follow-on satellite must be on-line by 2010, with development beginning by 2004.

			Net Income		Net Cash Flow	
	Acquisition	Transport	Worst Case	Best Case	Worst Case	Best Case
1984	$106.9M					($106.9M)
1985	560.1					(667.0)
1986	1030.2					(1697.2)
1987	1208.4					(2905.6)
1988	968.7					(3874.3)
1989	368.7	$21.8M				(4264.8)
1990			$18.0M	$6M		(4258.8)
1991			36.0	12		(4246.8)
1992			54.0	18		(4228.8)
1993			72.0	54		(4174.8)
1994			90.0	90		(4084.8)
1995			90	126		(3958.8)
1996			90	162		(3796.8)
1997			90	168		(3628.8)
1998			90	174		(3454.8)
1999			90	180		(3274.8)
2000			90	180		(3094.8)
2001			90	180		(2914.8)
2002			90	180		(2734.8)
2003			90	180		(2554.8)
2004	106.9		90	180		(2481.7)
2005	560.1		90	180		(2861.8)
2006	1030.2		90	180		(3712.0)
2007	1208.4		90	180		(4740.4)
2008	968.7		90	180		(5529.1)
2009	368.7	5.5	90	180		(5723.3)
2010			90	180		(5543.3)

For both best and worst cases, there is a continuing net cash loss over the life of the system, which means no break even point. Project rate of return is negative.

6.4.6 General Conclusions

Five major systems have been analyzed for investment potential. Electronic mail, Advanced TV Broadcast, Teleconferencing, National Information Service, and Personal Communications (Portable Telephone). They were analyzed for cash flow break even, and for project rate of return. Of the five, Personal Communications appeared to show the best potential, with cash flow break even in 11 years (best case) to 15 years, and a project rate of return at 12% (worst case) to 14% (best case). Advanced TV

shows the next best potential, with a cash flow break even in 9 years (best case) but a continuing loss out to the horizon time period of 2010 for the worst case. Project rate of return for the best case is 17%. National Information Service has a cash flow break even in 21 years (best case) and 22 years (worst case), and a project rate of return at 12% (best case) and 9% (worst case). Teleconferencing has a cash flow break even in 19 years (both cases), and a project rate of return at 11% (both cases).

Electronic mail, while showing apparently healthy revenues from operations, remained at a loss - a substantial loss. Electronic Mail income was unable to match the high investment costs needed to put even one system in operation. As a result, cash flow could not show a break even point in the 25 years.

6.5 ECONOMIC VIABILITY ASSESSMENT SUMMARY

Comparisons to current communications industries were made to derive average figures for net profit margin and non-hardware operational expenses. Rockwell International, in the companion study to this one, derived hardware costs related to these five initiatives for the first platform. Using market projections from Part 1 of the SAI study we derived a prediction of channels needed and sized the space systems requirements and estimated production and deployment costs as a function of time. With all the required cost data together a string of projected costs and revenues was calculated.

In the table below, the "Initial Capital" requirement reflects that amount of money required to establish the service and initiate revenue income. "Capital Before Breakeven" reflects the maximum debt incurred (cumulative cash flow) prior to the cash flow break even time when outlay and income balance. "Rate of Project Return" is an investment judgment tool which allows comparison of economic benefit gained relative to other potential investments. A return of 10% would mean that the investor is breaking even relative to a 10% discounted investment. All figures quoted are computed against a positive future scenario assuming needed structures, power and transportation technologies will come to pass.

SERVICE	INITIAL CAPITAL	CAPITAL BEFORE BREAKEVEN	RATE OF PROJECT RETURN
PERSONAL COMM	$420M	$420M	14%
ADVANCED TV	$200M	$200M	17%
NATIONAL INFO	$420M	$620 – $640M	17%
TELECONF	$254M	$2126M	11%
ELECTRONIC MAIL	$4,260M*	—*	—

*STRONG FUNCTION OF ASSUMPTIONS. BREAKEVEN NEVER ACHIEVED FOR POSTOFFICE TO POST OFFICE SYSTEM ASSUMED HERE.

The string of costs and revenues referred to earlier are presented graphically in Figure 6-3 with the number of years to achieve breakeven specified. It was not possible in this study to optimize the R & D investment, debt, market penetration rates, technical synergy and other factors affecting these curves. Also, a more aggressive market scenario could easily lead to economies of scale not realized here. Thus we feel the time to breakeven is generally conservative although not unattractive here considering the tens of billions of dollars potential annual revenue.

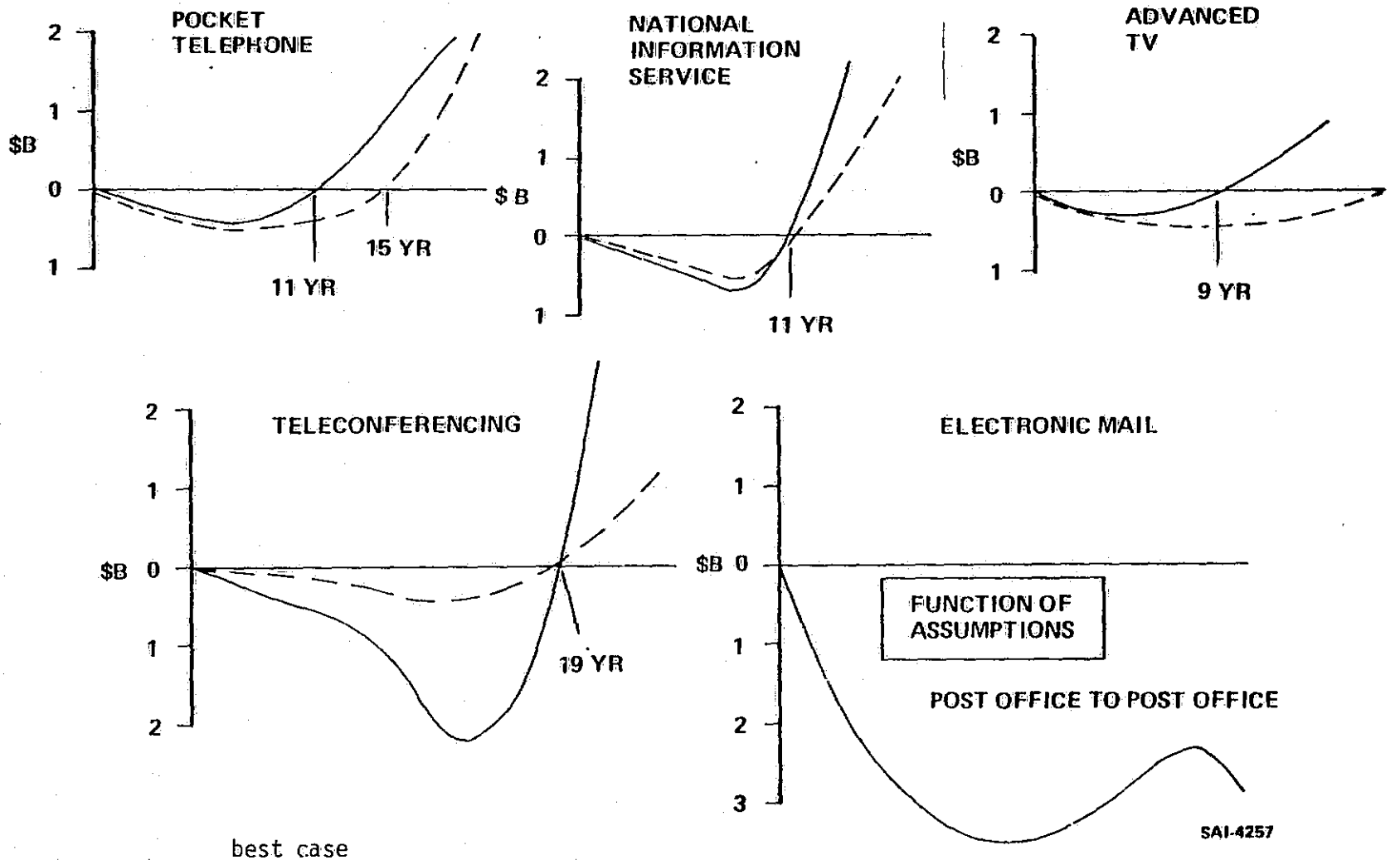


Figure 6-3. Cumulative Cash Flow Requirements

7. OBSERVATIONS AND RECOMMENDATIONS

Many of the results of this study are contained in the various sections of this report as data, observations or conclusions. Recommendations gleaned from outside sources (the industrial contacts) have also been previously presented. The purpose here will be to summarize data of particular interest to NASA and the industrial community and present a simple set of recommendations designed to promote the growth of Space Industrialization (SI).

7.1 OBSERVATIONS

Figure 7-1 summarizes the How and Why of Space Industrialization. The roles and related activities of government and industry feed the integrated SI activities that represents the summation of all future private and public SI programs. The motivators for such input and sponsorship are shown as a feedback loop. Three encompassing benefits to the public at large are shown as the integrated "value generation" of space industrialization. Net value generation is possible because a new and virtually inexhaustable resource, loosely called "space", is being utilized.

The corollary consideration of What and When were primarily addressed in Volume 2. At the highest aggregation level (general industrial category) the what and when can be displayed as in Figure 7-2. The rather sterile lines on this figure are wholly inadequate to express the latitude that each has according to the scenario assumed and the realities of capitalization and investment. Also the natural or "organic" growth potential of existing space industry (such as Intelsat and COMSAT) are not reflected on Figure 7-2. Thus the potential exists for the curves of each industry to swing toward greater or lesser revenue or benefit. We can say with some confidence that the direction and magnitude of that swing will depend completely on the investments made in the eighties. The technological, legal, institutional, international and regulatory hurdles must all be overcome in concert. The most important, however, is technological. The incentives are sufficiently strong that, given technical capability, the other hurdles will be overcome. The future of the United States and our system of free enterprise and democracy demand it. Therein lies the challenge to the NASA, the free worlds technological leader in space.

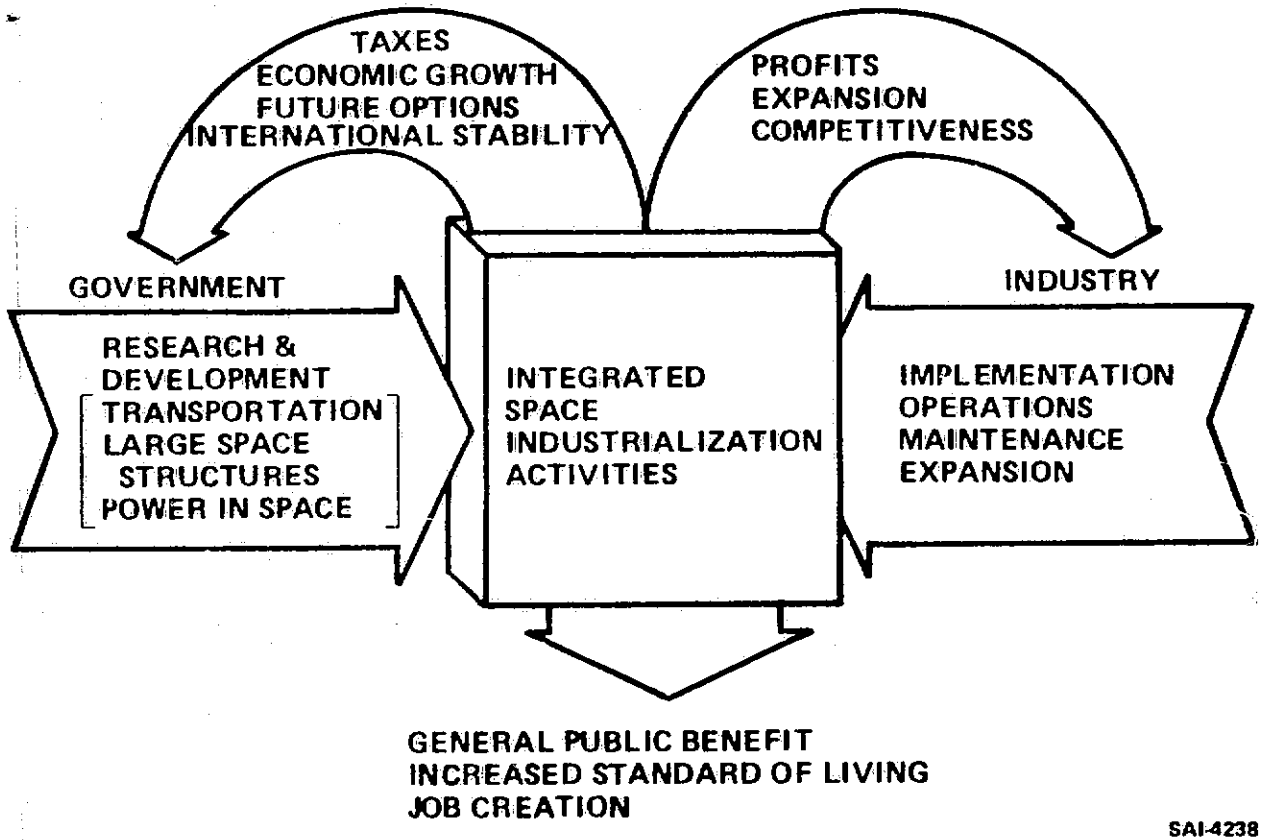


Figure 7-1. The How and Why of Space Industrialization

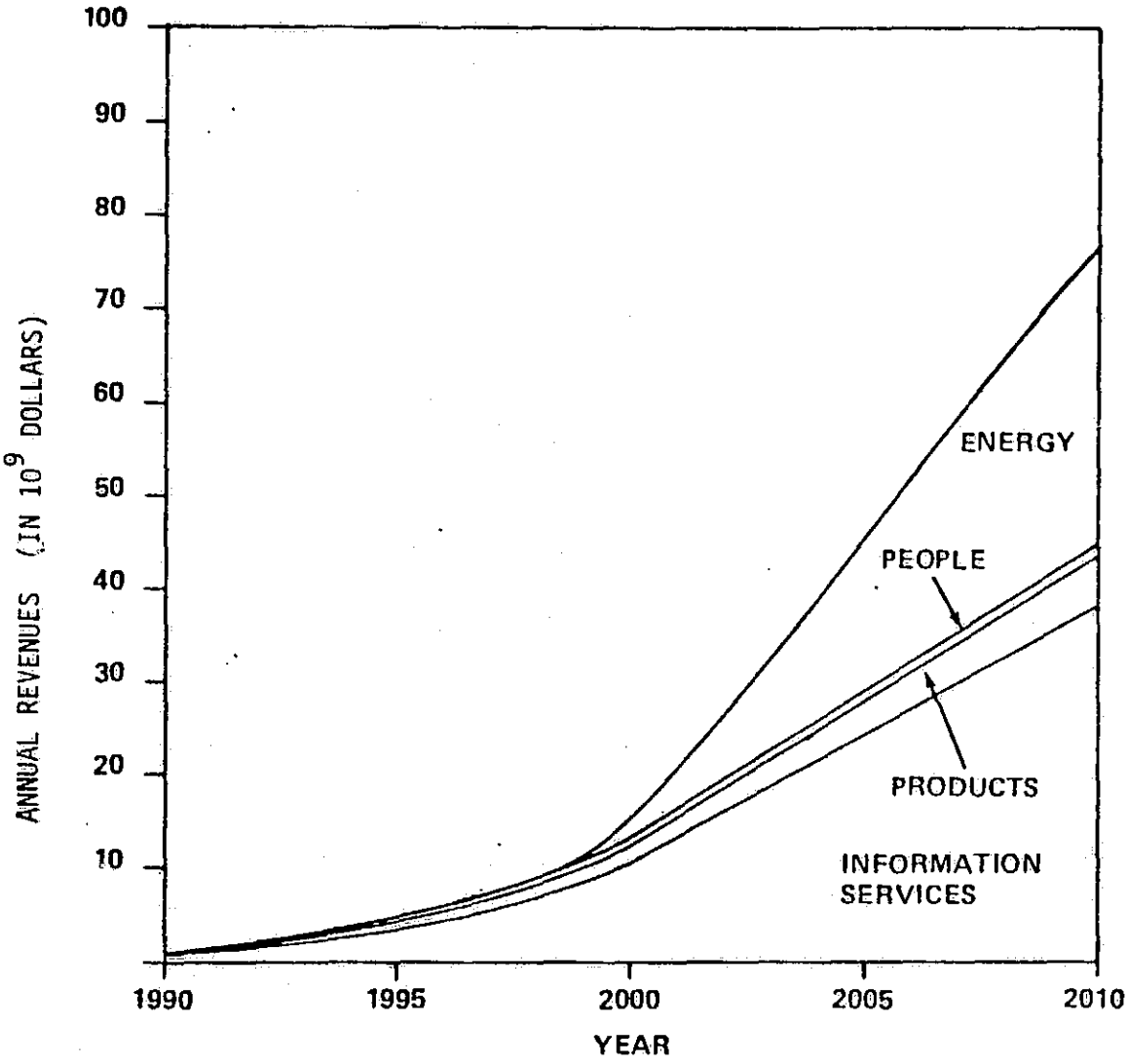


Figure 7-2. The Baseline Scenario Projection of What Space Industrialization Will Be Composed of and When Revenues Will Result

7.2 KEY TECHNOLOGIES

The most important spur to U.S. industry and U.S. world technical leadership will result from development of the following key technologies.

1. Large information systems
 - Structures - Large antenna of 10M to 200 M diameter.
 - Power - 20 KW to 10,000 KW.
 - Data processing - 100 to 1000 times present rate.
 - Transportation to high orbit - routine for maintenance, repair.
2. Materials space processing
 - Laboratory demonstration - goal oriented SPAR, Spacelab.
 - Prototype production - 10 to 100 pounds per day on some products.
 - Orbital support systems - power, structure, stability
 - Low cost transportation to low orbit -<$100/pound to really open market.
3. Large energy systems (use in space, broadcast to earth)
 - Structures - 0.5 KM to 15 KM
 - Power handling - 25 KW to 10 GW
 - Low cost transportation to high orbit - minimum feasible cost.

The projected benefits depend upon commercial operations that can only begin after the key technologies are available. The potential benefits are significant covering a spectrum of national concerns from jobs and balance of trade through standard of living and national pride.

Analysis of future scenarios, markets and resultant programs show that the result will be:

- Millions of jobs created
- Significant national economic growth
- Assurance of a long term favorable balance of trade
- Increased national and world-wide standard of living
- An enrichment of national pride and aspirations
- An invaluable option bank for responding to unforeseen future events

- Increases in knowledge probably unparalleled in the history of civilization

With the shuttle, we have the basis for space industrialization. We can utilize our lead by proper planning and timely implementation. The alternatives are clear---expanding the U.S. economy or face growing international competition.

In summary, the following points support an aggressive coordinated set of space industrialization initiatives in the public and private sectors.

- The revenue potentials exist today--we only lack the systems.
- All industries examined are exportable--the sooner they are available, the sooner we reap the benefits.
- Near term expenditures will create jobs, spur the economy, and be non-inflationary while creating the future.
- The times are right--if we wait they may not be.
- We can not exploit the shuttle if we don't know where we are going.
- Serious international competition is rapidly building.

The U.S. should begin actively supporting space industrialization by producing a major space power system, initiating the development of systems to support orbital manufacturing and developing large information systems. Substantial space power is needed for almost any industrialization. Materials manufacturing in orbit will require considerable demonstration and supporting systems. Large space information systems look the most commercially viable but the orders of magnitude scale-up needed will require demonstration and legal constraints (e.g., frequency allocations) may prove very troublesome.

This study has shown that commercially viable industries in Information Services, Energy and Products can be realized given the tools illustrated in Figure 7-3 for private enterprise to work with. Our analysis has also shown that public investment in these capabilities in the eighties will be paid back manyfold in the nineties and beyond. All indications are that Space Industrialization is the catalyst required to swing the United States and the world upward toward the next plateau of human

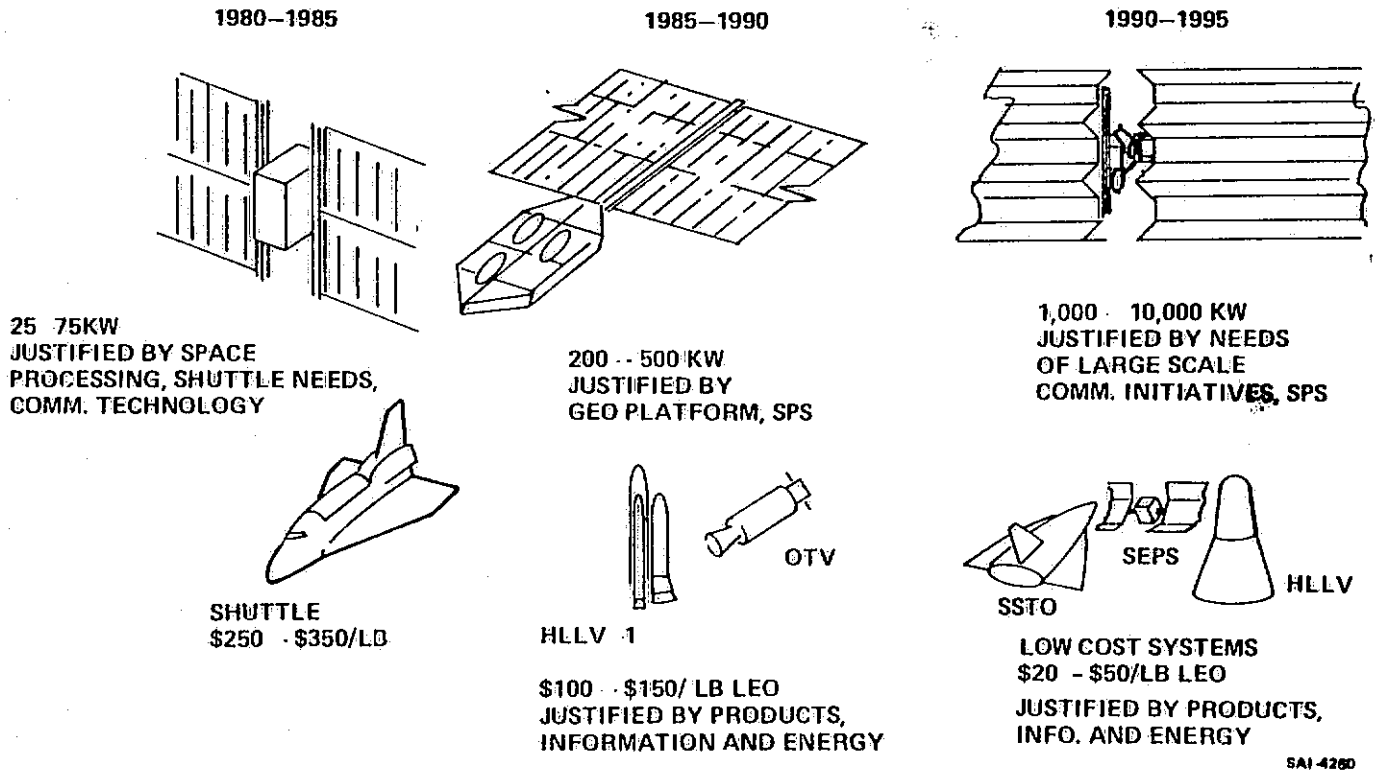


Figure 7-3. SI Structures, Power and Transport Requirements

achievement. This will be achievement in toto, not just in space or on the Earth but throughout the sphere of human endeavor. We believe that implementation of our recommendations and aggressive pursuit of the overarching concept of Space Industrialization will be concrete steps toward realization of these achievements.

7.3 RECOMMENDATIONS

The following paragraphs contain a series of "key recommendations" that are central to the issue of enhanced SI growth. A broad spectrum of recommendations were formulated, most of them very obvious in derivation. An example might be: "Develop close working relationships with other government agencies and apply SI to their problems and needs." Such recommendations, although central to some aspects of SI growth, are so obviously important that they are already being pursued.

The recommendations presented here, both general and specific, were selected based on their implementation implications. An inherent assumption is that a desire exists to take some predetermined actions to promote the growth of Space Industrialization. Given that assumption, a framework was formulated to provide overall planning guidance and more specific near term steps.

7.3.1 General Recommendations

In the simplest statement, these recommendations are as follows:

- Establish goals for SI in concert with various government agencies and private industry. Most will be in the eighties but some must be identified for the nineties and beyond to obtain overall guidance.

- Plan for the involvement of, and transition to, private industry at the earliest opportunity of all SI initiatives with public services becoming a customer. Consensus opinion is that this will maximize public benefit.

Space Industrialization is, as Ehricke termed it, the overarching concept capable of encompassing and coordinating future applications of space in the most beneficial manner. The individual initiatives in the industrial activities identified in this study should not be pursued as autonomous projects unto themselves. This study has shown that the concepts

of Space Industrialization are viable; that synergistic relationships are possible and desirable; and that industry/government cooperative planning and implementation are desirable and feasible. For various reasons industry will be loath to establish long term goals that carry near term investment commitments, thus government must lead in planning. The assumption of authority and responsibility by industry at an appropriate point in the life cycle of an initiative will require operating characteristics that should be established as part of the design and development process. In this area, industry must lead.

7.3.2 Specific Recommendations

- Incorporate in planning and act on all private industry recommendations discussed earlier.
- Establish an office for SI planning, integration and implementation reporting to the NASA administrator.
- Conduct the series of studies and formulate/implement the plans shown on Figure 7-4. The subjects and sequences are designed to converge on answers to questions delineated here.

The recommendations most strongly expressed by our industry contacts were presented earlier. Although the level of specificity varies, they are all expressions of a positive nature intended to enhance the near and long term growth of Space Industrialization.

One recurring message has appeared throughout this study when the origins and reasons for success of various projects was examined. It is that three elements were recurrent. They were:

1. The concept was technically sound.
2. Its evolution was well coordinated and the concepts and developments involved widely displayed.
3. Strong advocacy was provided by a small group of well informed, hard working people.

In recent years a fourth element has often been required: application to a need, although there are notable exceptions in recent years in the scientific community of course. It is these general observations that prompt our recommendation that a special Office for Space Industrialization Planning, Integration and Implementation be established to focus SI efforts.

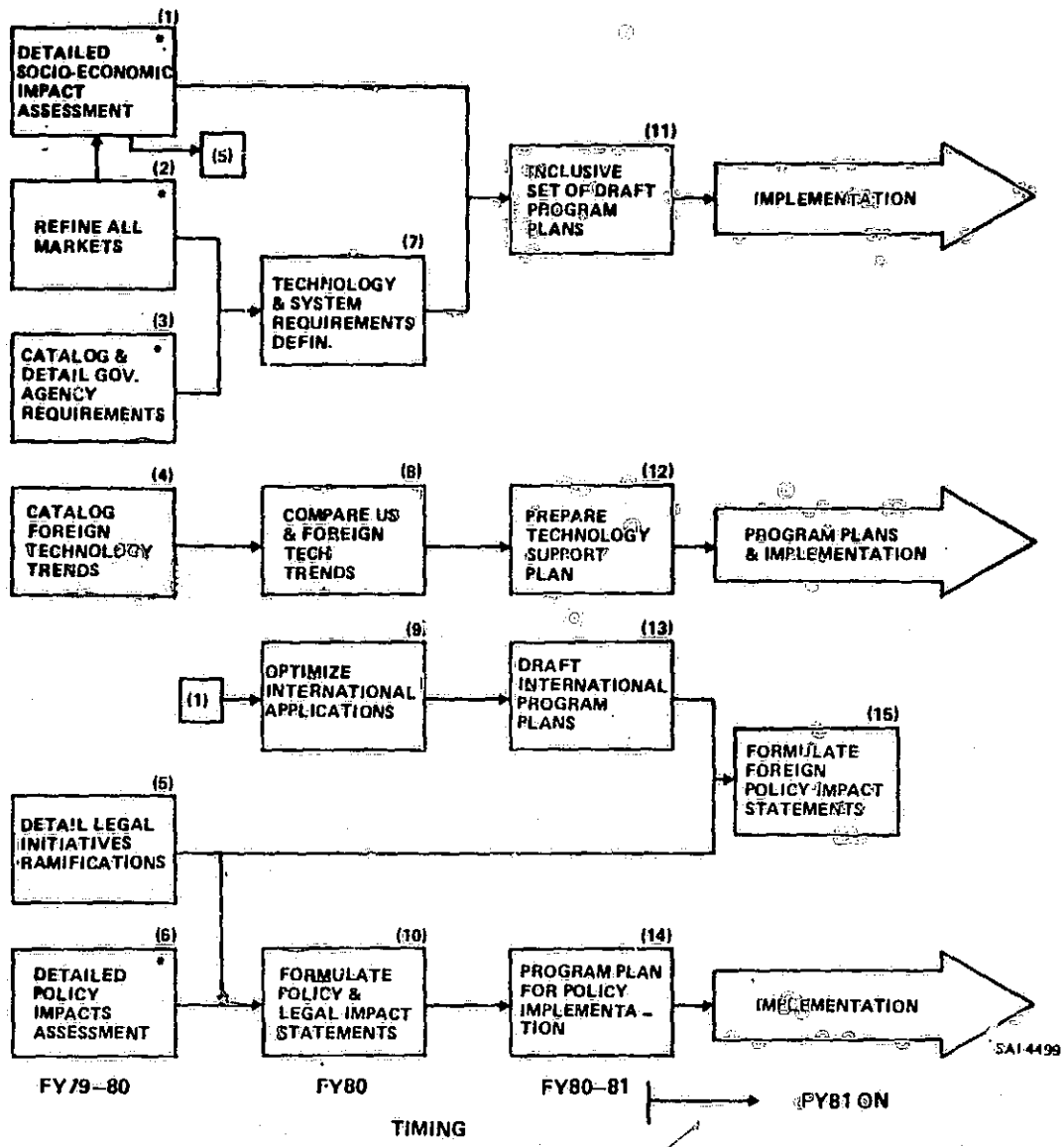


Figure 7-4. Recommendations for Study and Planning Activities Leading to Implementation of SI Programs

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Figure 7-4 provides a coordinated view of the individual assessments and planning actions which must come together to promote aggressive SI developments in the eighties. A number in parenthesis with each block keys that activity to the detailed description provided below. In column one, certain activities have been marked with an asterisk. This denotes studies and assessments of particular importance which should be initiated first if funding or other constraints preclude addressing all of the FY79 list.

The elaborations below provide not only purpose and description but also duration and level of effort which appear appropriate for each activity. These figures are based on experience and judgment developed during this study relative to the difficulty of addressing a particular subject. Hard charging, positive, aggressive program management is assumed in each case.

The overall implementation concept of Figure 7-4 is sound and proceeds as follows:

First, expend sufficient effort to delineate in detail the requirements and problems.

Second, integrate the requirements and find solutions to the problems.

Third, obtain agreements, funding and policy support.

Fourth, implement the plans and programs.

Fifth, continue planning but maintain long term goals.

The details of Figure 7-4 will undoubtedly change as new knowledge is gained. Without such an overall plan and an orchestration of government involvement in SI the sum of benefits that can accrue to the United States probably will not. It appears that private industry can not step up to the total challenge. If the public sector does not then we are probably witnessing one of the key non-actions leading to the general demise of the United States as a future leader. Unless space begins in less than ten years to generate a highly visible return on investment, we can expect an even greater public disinterest than previously experienced. At that point the shuttle will be considered a fraud and the whole concept of Space

Industrialization just another way to flim-flam the politicians into wasting money to keep overpaid bureaucrats on the payroll.

Our perceptions from talks, meetings, newspaper articles, etc. from all over the country is that we are being given the "benefit of the doubt". That will not last forever, probably only three or four years into the shuttle era. It will be necessary to extend that horizon to allow the key technologies to mature and really penetrate the commercial applications arena. That time can be gained through two approaches: (1) Implement experimental programs for the early-to-mid-eighties with strong public appeal and visible results. (2) Promote extensive industry/government involvement in every possible area. This will provide evidence that Space Industrialization is real and a genuine goal of the government agencies involved.

Space Industrialization exists and will grow. How rapidly and to what saturation level are the key questions. Acting on our recommendations will assure near optimum growth patterns.

7.4 STUDY RECOMMENDATION DESCRIPTORS

(1) Title: Preparation of a Detailed Domestic and International Socio-Economic Impact Assessment for Selected Space Industry Initiatives: 1980-2010.

Purpose: This study will provide certain data required by both industry and government to implement SI initiatives in the U.S. and other countries. The understanding of impacts in substantial detail provided by the study will allow decisions based on optimization of economic and social value generation. It will also provide a data base for intelligent and appropriate penetration of foreign markets.

Duration: Two years

Level of Effort: Twenty manyears.

Description: This study will take a set of key initiatives selected prior to SOW preparation and determine through detailed analysis what segments of society and the economy will be affected

in the U.S. and in certain other nations. After identification of these, reactions, changes and other impacts will be hypothesized and tested. Experimental and theoretical data will be brought together for each postulated impact and a total, interrelated assessment prepared.

(2) Title: Preparation of Detailed Market and Revenue Forecasts for the U.S. and Other Selected Nations.

Purpose: This study will provide the baseline data for the second part of study (1). It will also give much greater insight into value sensitivities for various domestic markets than was achieved in the SI study. Higher confidence data on potential markets is essential for effective long range planning.

Duration: One year.

Level of Effort: Six manyears.

Description: Using the SI Study as a departure point this study would use more formalized market analysis techniques and data sources to establish estimates. Sensitivities to a broad range of variables would be established. The satellite communications companies most likely to be involved in establishing the services would be worked closely with to establish probabilities on penetration rates and timing.

(3) Title: Catalog and Provide Details of Projected Government Agency Requirements for Space Related Capabilities (1980-2010)

Purpose: This study will provide a planning data base for projected space applications based on missions and public needs within the cognizance of all government agencies.

Duration: One year.

Level of Effort: Six manyears.

Description: A detailed, systematic study of the charter, goals, operational mode, funding and future missions of all government agencies will be conducted. From this, space initiatives will be identified that appear to enhance capability and/or save costs.

(4) Title: Define and Catalog Foreign Technology Trends

Purpose: A determination of present technology capabilities and projections for ten to twenty years of various foreign nations is required. This will support planning for stimulation of domestic technological competitiveness and provide data for drafting of several international program plans.

Duration: One year.

Level of Effort: Six manyears

Description: This study will systematically break down the elements of foreign space activities to the level indicative of technology and achievement. Work in progress to advance the identified technologies will be assessed to provide projections of future achievements as a function of time. Probabilities of achieving goals in performance, cost, reliability, etc. will be determined.

(5) Title: Determine the Current Status and Ramifications of all International and Domestic Legal Initiatives Related to Space Industrialization.

Purpose: This assessment will determine what agreements, laws or related legal actions are in effect, being considered or potentially evolving which could become limiting to U.S. initiatives in SI.

Duration: Eighteen months.

Level of Effort: Three manyears.

Description: The current family of SI related legal issues will be catalogued and interpretations categorized. Pending treaties, laws, agreements and upcoming regulatory meetings will be treated similarly. A set of probable impacts based on interpretations and postulated agreements will be derived. Finally, a preferred set of positions for the U.S. which will promote SI on upcoming issues would be delineated.

(6) Title: Determine the Current Status and Ramifications of United States Policies, Both Foreign and Domestic, Which Relate to SI.

Purpose: A detailed understanding of where U.S. policy is and where it is headed will be required to support decision making on SI proposals both foreign and domestic.

Duration: One year.

Level of Effort: Four manyears.

Description: A thorough research and consultation effort will compile past and current policies of the United States in both domestic and international affairs. Relations to SI will be postulated and modifications examined for impact. Prefered directions of change in policies will be expounded on.

(7) Title: Definition of Systems and Technology Requirements to Support Space Industrialization Growth.

Purpose: This effort will take the needs of the government and the desires of the market place (both domestic and foreign) and determine the hardware requirements in substantial detail.

Duration: Eighteen months.

Level of Effort: Fifteen manyears.

Description: This will be a fairly typical hardware, programming and cost study. Domestic and international needs and markets will generate requirements for use in designing hardward and planning its evolution.

(8) Title: Provide a Detailed Comparison of the Status of U.S. and Advanced Foreign Technologies Related to SI.

Purpose: This assessment will provide a comparison of the U.S. achievement in space industry related technologies as contrasted to the achievements of other nations determined in (4).

Duration: Twelve months.

Level of Effort: Four manyears.

Description: Study (4) will produce a data base on current and projected foreign technology at the system, subsystem and component levels. This assessment contrasts that data to the U.S. industry situation and addresses our lead, lag, or similarity at present and in the future.

(9) Title: Determination of the Requirements and an Associated Optimum Approach to Application of SI Initiatives to Certain International Needs.

Purpose: This study takes the socio-economic impact data from study (1) and derives appropriate specific applications of SI initiatives to support international program planning. A detailed data base for use in foreign and international applications planning will also result.

Duration: One year (initiated about 1 to 1½ years after study 1)

Level of Effort: Nine manyears.

Description: Using the socio-economic impact data of study (1) this assessment will look at specific applications and the associated programs on the basis of integrated international needs. The potential for synergistic efforts in applications and developments will be addressed in particular. From this will come recommendations on phasing of various programs (by nature and by country) and a step-by-step evolutionary bootstraping sequence where needed.

(10) Title: Provide an Assessment of Policy and Legal Status and Initiatives on the Growth of Space Industrialization

Purpose: The information from (5) and (6) will be incorporated into a single assessment of how the future of SI will be affected by policy/legal status and initiatives. A variety of Impact Statements will be formulated to provide to involved parties and decision makers.

Duration: Nine Months

Level of Effort: Four manyears.

Description: Studies (5) and (6) will have explored some possible effects from legal and policy matters. This task takes those impacts from (5) and (6) and integrates them, looking for relationships A series of specific impact statements for review by involved agencies and decision makers will be provided.

(11) Title: Prepare an Inclusive Set of Draft Program Plans for Phased Space Industry Growth.

Purpose: The output from (1) and (7) provide information from which detailed Program Plans for government and government/industry activities can be constructed.

Duration: Eighteen months.

Level of Effort: Nine manyears.

Description: Program Plans will be prepared in all areas of space industry activity. These will incorporate consideration of technology and system requirements, social integration, multi-government agency needs, economics, long and short range planning objectives, international markets, etc. From these detailed Plans will come the step-by-step implementation of Space Industrialization growth initiatives.

(12) Title: Prepare a Technology Support Plan

Purpose: This Plan will organize the stimulation of technologies identified in (8) as requiring subsidization of international technical competitiveness is to be obtained or retained.

Duration: Six months.

Level of Effort: Three manyears.

Description: Information on U.S. and foreign technology trends will be transformed into a set of plans whose implementation

will support increased competitiveness in SI related activities.

(13) Title: Provide Drafts of a Set of International Program Plans for SI Implementation.

Purpose: These Plans will be used to coordinate with appropriate nations for purposes of SI implementation and growth. The backbone of foreign policy positions on SI would be initially set here.

Duration: Eighteen months.

Level of Effort: Nine manyears.

Description: Program Plans (in draft form) will be prepared in all areas of international space industry activity which involves the United States. These will incorporate consideration of technology and system requirements, social integration, multi-government agency needs, economics, long and short range planning objectives, international markets, etc. From these detailed Plans will come the step-by-step implementation of Space Industrialization growth initiatives.

(14) Title: Prepare a Program Plan for Implementation of Policies Related to Space Industrialization

Purpose: The results of this effort will be a step-by-step plan for evolution of national policies within various agencies. The goal will be to tailor laws, rules and policies in the United States amenable to strong SI growth.

Duration: Eighteen months.

Level of Effort: Twelve manyears.

Description: The Program Plan will be derived from consideration of policy and legal impacts compiled in (10). A multitude of tradeoffs and iterations will be necessary to select optimum paths and provide for contingencies.

(15) Title: Formulation a Set of Foreign Policy Impact Statements Based on SI Initiative Projections

Purpose: These impact statements will provide an assessment to policy makers of the probable results of certain positions to be taken and will recommend prefered policy.

Duration: Twelve months.

Level of Effort: Four manyears.

Description: A series of foreign policy issues will result as SI plans are implemented. This activity will postulate the issues, assess the ramifications and provide policy decision makers with impact projections and prefered positions.

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